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Essays on Differentiated Pension Systems

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Ogni opinione ha due tempi.
Uno al passato, su ciò che è meglio.
Uno al presente, su ciò che è più adatto.

Francis Bacon

Essays on Differentiated Pension Systems

Abstract

This thesis is composed by three chapters in the form of self-contained works.
The first work builds up a model to analyse the interaction between flexible contracts and pension systems in interconnected environment which allows obtaining heterogeneous labour careers featuring life cycle unemployment, flexible wage-tenure contracts. These are used as base to compare performances of two standard pension regimes, a Defined-Benefit (DB) and a Defined-Contribution (DC), in terms of financial sustainability and adequacy (income maintenance, inequality and poverty in old age). It results that a DC is more sustainable and adequate than a DB, despite the latter delivers higher pensions. Two standard variants of DC are also presented, in which the pension contribution rate is differentiated by worker's age (DAC) and tenure of contract (DTC). These differentiated designs outperforms the standard DB and DC in all four dimensions.
The last two chapters are empirical works which focus on the Italian population. They document a persistent and not decreasing heterogeneity in life expectancy across geography and education, respectively, and update the empirical evidence until recent years. Gender and age specificities are also considered. Unlike previous works, these two contributions use available data to cover also the last decade or so. The systematic dispersion of longevity, interacting with a public pension system, triggers an implicit tax/subsidy mechanism penalising/favoring tho who live less/more than commonly assumed by the pension formula through a homogeneous factor for residual life expectancy. These rates are estimated and a corrective policy based on gender-differentiated is proposed. Application of gender-specific values for life expectancy alleviates the intensity of the implicit transfer mechanism.
Overall, these works call for a differentiated design of public pension regimes in the face of an increasing heterogeneity both before retirement, in terms

of labour careers and, at retirement, in terms of residual life expectancy. Differentiation of contribution formula, by worker's age or by tenure of the contract, and of pension formula, by worker's gender, can be promising policies aimed at restoring the financial sustainability, adequacy, actuarial fairness and progressivity of public pension systems in an ageing heterogeneous society.

Flexible Contracts, Pension Systems and Differentiation of Contributions

Fabrizio Culotta*

Abstract

This work builds an OLG model to highlight the interaction between flexible labour contracts and unfunded pension systems.
The model features life cycle unemployment in the short-run, wage-tenure contracts and a public pension system. Model dynamics is able to produce relevant demographic, labour market and pension statistics in a unified modelling framework. It also reproduces some empirical patterns observed in Europe and Italy over the last two decades. In this environment, performances of Defined-Benefit (DB) and Defined-Contribution (DC) pension regimes are compared in terms of financial sustainability and pension adequacy expressed as income maintenance, inequality and poverty among retirees. A differentiated design of DC is also presented, where the contribution rate is differentiated by worker's age the tenure of the contract.
DB offers higher pensions, it is less sustainable than DC. DC is associated to lower pension inequality and poverty. Differentiated pension regimes outperforms the standard DC in all dimensions but not in inequality. A sensitivity analysis to model paramters and to alternative scenarios confirms these conclusions.
Despite the model is mechanical, a behavioural extensions regarding a reservation strategy in the context of wage-tenure contracts is also considered. Several extensions are identified and left to future research.

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Keywords: Life Cycle, Unemployment, Wage-Tenure Contracts,
Differentiated Taxation, Pension Systems, Adequacy.

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1 Introduction

Over the last quarter of century, labour markets and pension systems have been deeply reformed. From one side, an increasing demand for labour flexibility created new types of contracts, e.g. part-time and temporary, beside the typical full-time and permanent relation (Atkinson, 1984; Wilthagen and Tros, 2004; Corvers et al., 2012). Figure 1 shows the time series for each type of contracts in EU-15 and, in particular, in Italy over the years $1997 - 2015$.

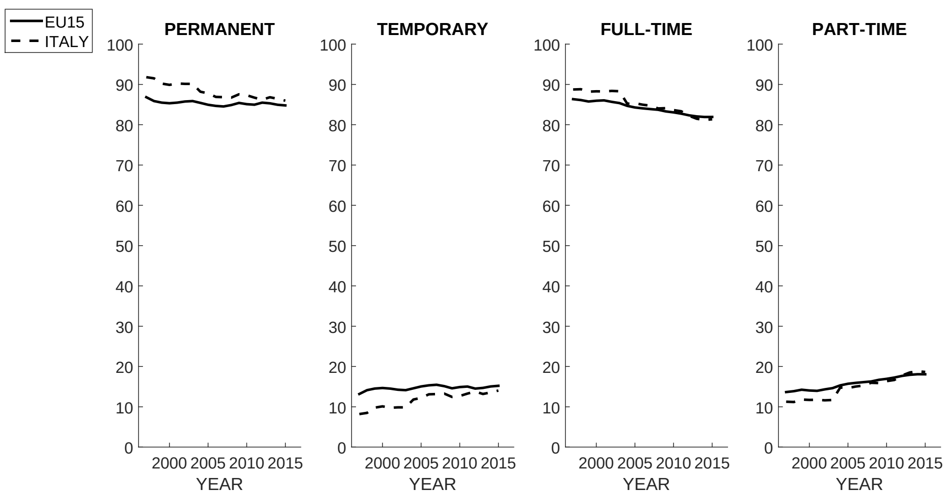


Figure 1: *Employment share (%) in full-time, part-time, permanent and temporary contracts over 1997-2015 in EU-15 and in Italy. Source: author's own elaboration on OECD data.*

The resulting coexistence of different contracts has contributed to lower the average employment tenure through less costly layoffs and more frequent terminations. In some countries, the proliferation of flexible contracts has actively contributed to the raise of inequality especially for middle-aged and old workers.

From the other side, population ageing urged politicians to reform the eligibility requirements to access pension benefits. Common pension reforms increased the minimum numbers of years of contributions required, tha in case of interrupted careers make difficult for workers to be fully entitled to old-age pensions Hinrichs and Jessoula (2012). The process of population ageing is still a persistent phenomenon, as shown in figure 2. The most extreme age groups, i.e. $15 - 24$ and $65+$, exhibit opposite trends. While the share of population aged $15-24$ declined from 13.29% in 1997 to 11.25% in 2016, that of age 65+ increased from 15.6% to 19.72%. All other age groups steadily remain within the range of $5-8\%$. Profiles for Italy, one of the most longeve conutry in the world, show a similar pattern. Age group $15-24$ reduces its share from 13.3% in 1997 to 9.8% in 2016. Those aged 65+ increases from 17.2% in 1997 to 22% in 2016.

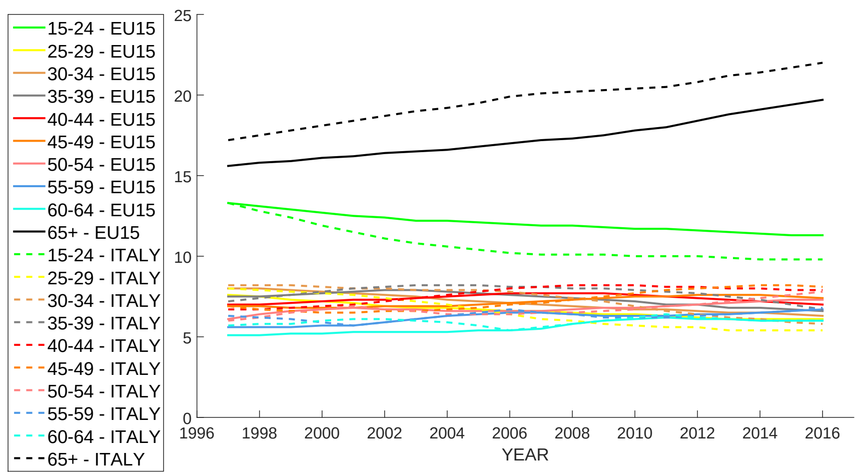


Figure 2: *Population share (%) by 5-years age classes for EU-15 and for Italy during* $1997-2016$*. Source: author's own elaboration on Eurostat data.*

From a dynamic perspective, figure 3 population ageing can also be depicted in terms of evolution of share of population by age classes.

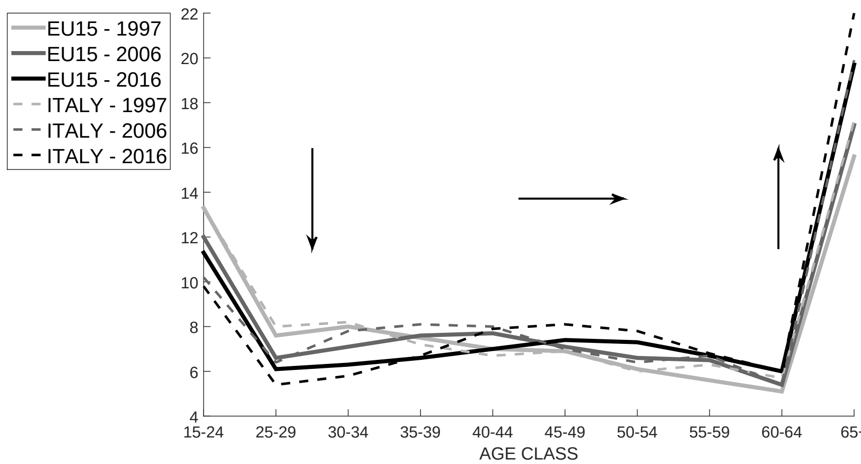


Figure 3: *Distribution of population share (%) by 5-years age classes for the averaged EU-15 and for Italy in 1997, 2006 and 2016. Source: author's own elaboration on Eurostat data.*

As expected, the median class increases from $25-35$ in 1997 to $30-40$ in 2006 to $40-50$ in 2016.
In order to react to population ageing as well as to past fiscal imbalances, governments have been forced to undertake pension reforms. Retrenchment measures ranged from increases in mandatory retirement age to shifts from DB to DC, to reductions in pension benefits, to tighter eligibility requirements, to penalties for early retirement. This notwithstanding, pension expenditure remains a the biggest component of public expenditure among Europeans countries, and old-age pension is even increasing since 2010 as shown in figure 4.
Supplementary schemes in II (occupational) or III (private) pension pillars have also been proposed and publicly incentivised but without satisfactory results, apart from those countries where participation has been set on mandatory basis[1].

[1]Eurostat data for EU-12, show that all countries maintain a level of pension assets on GDP below 15% throughout the period 2001-2016. Notable exceptions are the Netherlands (above 100%), Denmark and Finland (both around 50%).

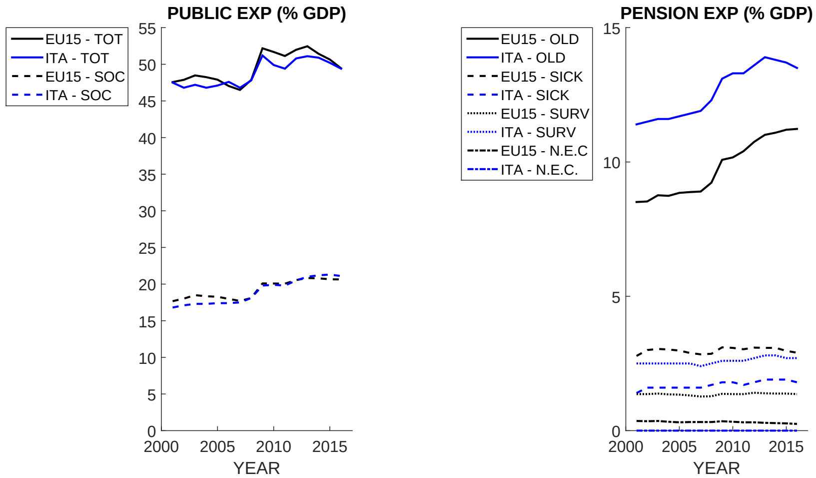


Figure 4: *Public pension expenditure (% GDP) over* 1997 − 2016 *distinguished as total public expenditure (TOT), social security (SOC), old-age pension (OLD), sickness pension (SICK), survivorship pension (SURV) and non elsewhere classified pension (N.E.C.). Source: author's own elaboration on Eurostat data.*

In a context of unfunded pension systems, a falling job tenure weakens the pension contribution inflow and, *ceteris paribus*, the associated fiscal balance. While the well-known population ageing implies an increase in the pension outflow due to increased longevity, shorter and more interrupted careers directly lower resources withdrawn from currently employed workers to finance currently retired workers. In such a scenario, contract flexibility is likely to lower the extensive margin of pension contributions, i.e. the number of contributors per unit of employment. If, as often the case, atypical jobs are also associated to lower wages, contract flexibility also reduces the intensive margin of pension contributions, i.e. the level of pension contributions per unit of employment. Pension contribution margins are thus affected by labour market institutions governing employment flows, i.e. the extensive margin of pension contribution, and labour wealth, i.e. the intensive margin. European countries differ not only in terms pension regimes, but also in terms of labour market institutions. These differences are likely to have a different impact on pension systems. Indeed, the same institution can have a different impact depending on the specific pension regime in place. Following this line of reasoning, the analysis of the relation between contract flexibility, from one side, and financial sustainability and adequacy of pension regimes, from the other, can be a good reason to study the interplay between labour markets and a more appropriate design of the public pension system[2].

From a theoretical viewpoint, the connection of a life cycle model of unemployment featuring wage-tenure contracts in order to analyse the labour-pension nexus has not been proposed yet in the economic literature. This work tries to fill this gap by building a simple OLG model featuring life cycle unemployment, wage-tenure contracts and an explicit post-retirement period in which performances of standard and differentiated pension regimes are compared. In doing so, this work answers the following research question: in an economy featuring unemployment and flexible contracts, how traditional DB and DC public pension regime behave in terms of financial sustainability and adequacy? Can a differentiated design lead to an improvement?

As byproduct, this work offers a modeling framework where labour careers are endogeneously produced and performances of pension systems are explicitly interconnected. This integrated framework could help to have a more transparent understanding of the interplay between labour markets and pension systems.

Structure. This paper is organised as follows. Section 2 reviews the literature about unemployment and pension systems. Section 3 describes and calibrate the model. Section 4 presents baseline results. Section 5 concludes. Appendices A and B provide sensitivity analysis of model outcomes to changes in model parameters and alternative scenarios, respectively. Appendix C reports the empirical validation of the model. Finally, appendix D obtains an explicit formula for the reservation wage in the context of flexible wage-tenure contracts.

[2]Note that since 2012, in EU, the Social Protection Committee through the Social Protection Performance Monitor also poses attention on labour market exclusion, pension adequacy and poverty. This seems to embrace a more integrated view between labour markets and pension systems.

2 Literature Review

The economic literature on labour markets and pension systems has been developed on two distinct branches. While equilibrium unemployment theory has become the reference modeling framework for labour market dynamics, almost all works explicitly dealing with pensions adopt a Neoclassical framework where employment is assumed as an absorbing state and wage is retrieved via a factor price equation[3]. Instead, labour market frictions matters when one approaches to the analysis of retirement and the dynamics of pension systems De La Croix et al. (2013); Hairault et al. (2015).

The theory of equilibrium unemployment analyses the dynamics of workers flows and wages, stressing the role of labour market institutions Pissarides (2000). This framework has been extended along several directions. In particular, in a context of random search, the single-price wage offer has been extended to a bi-dimensional wage-tenure structure to study the problem of worker's retention Burdett and Coles (2003, 2010); Stevens (2004); Friedberg et al. (2006)[4] For models with directed search and wage-tenure contracts (Shi, 2009; Rudanko, 2009; Tsuyuhara, 2016). Unfortunately, none of these models considers a life cycle dimension, which is an essential feature to study retirement and pension systems. Also works that focus on contract duality, i.e. the coexistence of temporary and permanent contracts, abstract from life cycle considerations (Smith, 2007; Berton and Garibaldi, 2012; Kahn, 2012; Faccini, 2013; Berson and Ferrari, 2015; Di Cintio and Grassi, 2015; Osuna and Garcia-Perez, 2015; Cahuc et al., 2016; Tejada, 2017).

On the contrary, life cycle models of frictional unemployment, introduced by Cheron et al. (2013), are able to reproduce the U-shaped age-profile of unemployment. Saint-Paul (2009) shows that presence of a mandatory age for retirement makes workers less employable once they approach to retirement, so called *end-game effect*. Hairault et al. (2010, 2015) investigate the relation between employment status and early retirement choices to conclude

[3] Within the literature of macroeconomic growth, Corneo and Marquardt (2000); Brauninger (2005); Ono (2007, 2010); Thøgersen (2010) add unemployment to the analysis of pension systems but within a three-period OLG framework. Abstracting from unemployment, see also Sommacal (2006) for a 2-period OLG model which introduces endogeneous labour supply to analyse the intergenerational distribution associated to pension systems.

[4] Indeed, the first model with bi-dimensional contract was that of McCall (1970), presented as (incomplete) extension of single-price reservation wage model.

that they retire earlier if unemployed since being closer to retirement age reduces the probability of finding a job, so called *distance-to-retirement effect*. Unfortunately, these works featuring life cycle unemployment focus either on single-price wage posting, as Saint-Paul (2009); Hairault et al. (2010); Sabatier and Legendre (2017), or wage bargaining, as Khaskhoussi (2009); Cheron et al. (2013); De La Croix et al. (2013); Hairault et al. (2015); Batyra et al. (2017)[5]. Instead, rigidities implied by wage-tenure contracts can help to better understand unemployment dynamics Burdett and Coles (2003). Moreover, these life cycle models do not consider a post-retirement, nor they analyse the implied distribution of pension wealth. They focus on the understanding on the relation between labour market conditions in old age and early retirement behaviour.

Overall, no model of frictional unemployment offers a life cycle framework where firms post wage-tenure contracts, essential feature to analyse the interplay between contract flexibility and the performances of pension systems. Out the literature on frictional models, De Freitas et al. (2011) for France and Bravo and Herce (2017) for Spain and Portugal are the first works that explicitly focus on the impact of unemployment spells on pension entitlements. For example, Bravo and Herce (2017) analyses the Portuguese and the Spanish DB public pension systems to conclude that, unless occurring within the time window adopted to compute the reference wage, unemployment breaks do not impact on pension entitlements. Accordingly, this can be considered the first work which combines unemployment and flexible wage-tenure contracts in a complete life cycle framework to generate individual labour careers which, on their turn, are used to study performances of pension regimes in terms of financial sustainability and pension adequacy among retirees. Implicitly, in doing so, for the first time, this work tests the design of DC pension regime, as proposed by Castellino (1969), to a context of frictional unemployment and flexible contracts and proposes a new variant based on the differentiation of the pension contribution rate along worker's age and the tenure of the offered contract.

[5] In particular, Batyra et al. (2017) shows that a time-declining workers' bargaining power and matching efficiency are responsible for early retirement in France and Germany. The argument of a weaker bargaining power can also justify the increase of contract flexibility which increases unemployment among old workers and, thus, the incidence of early retirees Hairault et al. (2010).

3 Model

3.1 Life Cycle, Unemployment and Flexible Contracts

Consider an OLG economy populated by workers receiving flexible wage-tenure contracts when unemployed and a public pension system run on an unfunded basis. The economy is stationary since there are no aggregate shocks. In each period a cohort composed by I workers indexed by i enter the labour market aged $a = a_{min}$ as unemployed. The model abstracts from labour market participation, so labourforce and population coincide. Workers retire when aged a_{ret} and leave the economy when they reach $a_{max} > a_{ret}$. Workers who exit are replaced by new entries so there is not labourforce growth.

Workers are heterogenous not only along the age dimension. Within the same cohort they also differ with respect to their labour market careers. Workers do not interact, they have no choices nor endowments and supply an indivisible amount of labour [6]. When active, i.e. $a < a_{ret}$, workers can be either unemployed, $\mu_{i,a} = 1$, or employed, $\mu_{i,a} = 0$.

If unemployed, the i-th worker aged a receives a wage-tenure contract $(w, t)_{i,a}$ according to a random posting mechanism[7]. A wage-tenure contract is composed by a wage $w_{i,a} \in [w_{min}, w_{max}] \subset \mathcal{R}_{++}$ and a tenure $t_{i,a} \in [1, a_{ret} - a - 1] \subset \mathcal{N}^*$, where each component is independently drawn from its own pdf $f_W(\cdot)$ and $f_{T,a}(\cdot)$ respectively[8]. This assumption of inter-independence allows to distinguish between changes in the extensive and intensive margins of pension contribution associated to changes in wage and tenure components

[6] In this baseline version, extensive and intensive margins of labour supply are excluded. The extensive margin of labour supply is formulated in terms of reservation-wage strategy in appendix D. While the intensive margin, modelled as a choice of search, is left to further research. Aguiar et al. (2013), using MTUS data, reports that age profile of search intensity varies across countries. In Italy such a profile is constant whereas elsewhere is monotonically decreasing (France, Germany, Spain, UK) or hump-shaped (US).

[7] Regarding wage determination, Brenzel et al. (2013) finds for Germany concluding that posting is about two-third of employment. This concerns employees in large firms, public sectors, firms covered by collective agreements, part-time and fixed-term contract. See also Hall and Krueger (2012) for the US labour market.

[8] In the literature of frictional unemployment, also Hairault et al. (2010) and Rendon (2006) assume that wage draws come from an exogenous distribution (Log-Normal and truncated Log-Normal, respectively), while Low et al. (2010); Lammers (2014); Michelacci and Ruffo (2015) estimate the wage distribution from empirical data. But all these models assume a unidimensional structure for single-price employment contracts.

of contracts, respectively. On the other side, it does not allow to capture the positive relation between wage level and contract duration. As in Rudanko (2009), where offered contracts are specified as a collection of wage payments conditional on continuation of the employment relation, a wage-tenure contract $(w,t)_{i,a}$ drawn by i-th worker when unemployed and aged a is specified as a sequence of $t_{i,a}$ payments of wage $w_{i,a}$ indexed by τ. The associated wage schedule is defined as:

$$(w,t)_{i,a} = \{w_{i,a+1}, ..., w_{i,a+t_{i,a}}\} = \{w_{i,a+\tau}\}_{\tau=1}^{t_{i,a}} \tag{1}$$

where $w_{i,a+\tau} = w_{i,a}$ for any $\tau = 1, ..., t_{i,a}$ since wage growth and severance payments are excluded from the model. With probability ϕ, which represents the hazard from unemployment, the i-th worker will be hired with contract $(w,t)_{i,a}$ starting from next period when aged $a+1$, otherwise he will remain unemployed also next period. This assumption of one period lag from unemployment to employment status is justified by the fact that wages are paid one month after the beginning of the employment relation. Moreover, as in Cheron et al. (2013), this implies that for unemployed workers the last period of a fruitful job search is two periods before retirement.
When the employment relation is ongoing, i.e. when $\tau < t_{i,a}$, the i-th worker can be fired according to the tenure-specific probability $\lambda_{i,a} = \lambda_{i,a}(\lambda, t_{i,a})$ with λ representing the unconditional firing probability[9]. If not fired, he will remain employed next period, i.e. $\mu_{i,a+1} = 0$. Instead, if the employment relation is terminated, i.e. $\tau = t_{i,a}$, he will become unemployed next period. Overall, the individual unemployment dynamics obeys to the following non-homogenous first-order difference equation evolving in discrete time:

$$\begin{aligned}
\mu_{i,a+1} &= \mu_{i,a}(1-\phi) + (1-\mu_{i,a})[(1-\varepsilon_{i,a})\lambda_{i,a} + \varepsilon_{i,a}] \\
&= \mu_{i,a}(1-\phi) + (1-\mu_{i,a})\left\{\left[1-\left(1-\lambda_{i,a}\right)^{t_{i,a}-1}\right]\lambda_{i,a} + \left(1-\lambda_{i,a}\right)^{t_{i,a}-1}\right\} \\
&= \mu_{i,a}(1-\phi) + (1-\mu_{i,a})\left[\lambda_{i,a} + \left(1-\lambda_{i,a}\right)^{t_{i,a}}\right]
\end{aligned} \tag{2}$$

where $\varepsilon_{i,a} = 1$ if the contract of worker i when aged a has arrived to the last payment, i.e. it has terminated, and zero otherwise. The second line is

[9] Since workers cannot voluntarily quit the employment relation, job fires and separations are used as synonymous. An *ad hoc* is to include voluntary quits. This is left to future research

obtained by noting that $\varepsilon_{i,a}$ expresses the probability of arriving at the end of the contract, i.e. not being fired before. In symbols:

$$\varepsilon_{i,a} = Pr[\tau = t_{i,a}] = \prod_{\epsilon=1}^{t_{i,a}} Pr[\tau = \epsilon] = (1 - \lambda_{i,a})^{t_{i,a}-1}$$

Under this form, the tenure of contract $t_{i,a}$ explicitly enters into the structural equation for unemployment dynamics at individual level. Overall, workers aged a will be unemployed if they do not receive a job offer when unemployed, $\mu_{i,a}(1 - \phi)$, if hey are fired when employed, $(1 - \mu_{i,a})(1 - \varepsilon_{i,a})\lambda_{i,a}$ or if the employment contract terminates, $(1 - \mu_{i,a})\varepsilon_{i,a}$. Even if unemployment is involuntary since workers have no choices, it is frictional due to the role of probabilities of job arrival ϕ and separation $\lambda_{i,a}$ as wella as the tenure of the employed contract $t_{i,a}$. Figure 5 provides a minimal example in the form of a tree representation for the dynamics of a worker associated to a job offer $(w, t)_{i,a}$ for $t_{i,a} = 2$.

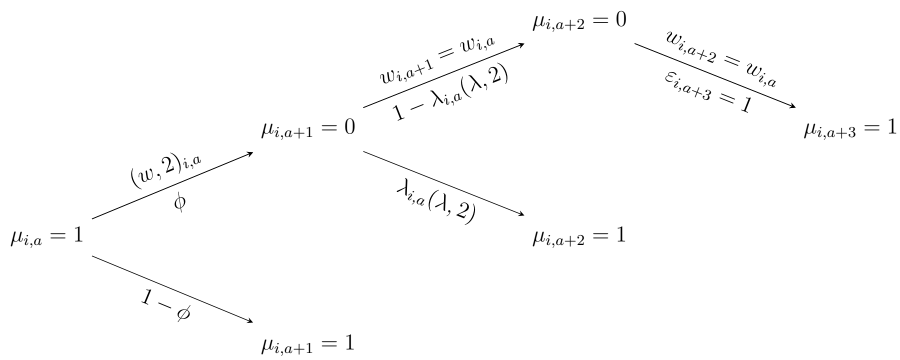


Figure 5: *Binomial tree associated to a wage-tenure contract $(w, t)_{i,a}$ of wage $w_{i,a}$ and tenure $t_{i,a} = 2$ drawn when worker i is aged a and unemployed.*

At aggregate level, the cohort-specific steady-state dynamics of unemployment for workers aged a, μ_a^*, is given by:

$$\begin{aligned}\mu_a^* &= \frac{(1-\varepsilon_a)\lambda_a + \varepsilon_a}{\phi_a + (1-\varepsilon_a)\lambda_a + \varepsilon_a} \\ &= \frac{\lambda_a + (1-\lambda_a)^{t_a}}{\phi_a + \lambda_a + (1-\lambda_a)^{t_a}}\end{aligned} \tag{3}$$

where $\phi_a = \phi\frac{\sum_i^I \mu_{i,a}}{I}$, $\varepsilon_a = \frac{\sum_i^I \varepsilon_{i,a}}{I} = \frac{\sum_{i=1}^{I}(1-\lambda_{i,a})^{t_{i,a}-1}}{I}$ and $\lambda_a = \frac{\sum_i^I \lambda_{i,a}}{I}$ represent hiring, termination and separation rates among workers aged a. In the second line, $t_a = \frac{\sum_{i=1}^{I} t_{i,a}}{I}$ represents the average tenure of contracs among employed workers aged a. Note that, unlike the canonical search and matching framework of equilibrium unemployment Pissarides (2000), a new friction is considered, namely rigidities from wage-tenure lotteries. This adds a new institution in the labour market, i.e. the contract termination rate, which allows considering workers being unemployed because of the natural expiration of the contract. Together, equations 1 and 2 produce heterogeneous labour market careers at individual level, a novel feature in the literature of frictional labour market models.

When employed with an ongoing contract with wage $w_{i,a}$ and tenure $t_{i,a}$ for a current tenure $1 \leq \tau \leq t_{i,a}$, the i-th worker pays pension contributions $pc_{i,a,ps}$ defined as the product between wage and the pension contribution rate $r_{pc,ps}$ specific to each pension regime ps. When retired, i.e. $a = a_{ret}$, each worker receives a pension benefit $p_{i,a_{ret},ps}$ depending on his own labour career[10]. A pension regime ps specifies a rule for pension contributions $pc_{i,a,ps}$ and a formula for pension benefits $p_{i,a_{ret},ps}$ which will be defined next. When workers reach age a_{max}, they exit the economy.

Performances of each pension regime are evaluated in terms of financial sustainability and adequacy. Financial sustainability B_{ps} of each unfunded pension system are measured as the difference between current inflow of pension

[10]The model abstracts from inflation and pension benefits remain constant over time. Also the relation between pension benefit and tax loading is not considered. Instead, in real world, pension benefits are either back-loaded, i.e. pension contributions are not deductible and pension income is tax-exempted, or, viceversa, front-loaded (e.g. in Italy).

contributions $pc_{i,a,ps}$ and current outflow of payments $p_{i,a,ps}$:

$$\begin{aligned} B_{ps} &= \sum_{a=a_{min}}^{a_{ret}-1} \sum_{i=1}^{I} pc_{i,a,ps} - \sum_{a=a_{ret}}^{a_{max}-1} \sum_{i=1}^{I} p_{i,a,ps} \\ &= \sum_{a=a_{min}}^{a_{ret}-1} \sum_{i=1}^{I} (1-\mu_{i,a}) r_{pc,ps} w_{i,a} - \sum_{a=a_{ret}}^{a_{max}-1} \sum_{i=1}^{I} p_{i,a,ps} \\ &= \sum_{a=a_{min}}^{a_{ret}-1} \underbrace{\left(1 - \frac{(1-\varepsilon_a)\lambda_a + \varepsilon_a}{\phi_a + (1-\varepsilon_a)\lambda_a + \varepsilon_a}\right)}_{\text{Extensive Margin}} \underbrace{\left(r_{pc,ps} w_a\right)}_{\text{Intensive Margin}} - \sum_{a=a_{ret}}^{a_{max}-1} p_{a,ps} \end{aligned} \tag{4}$$

where $w_a = \frac{\sum_i^I w_{i,a}}{I}$ and $p_{a,ps} = \frac{\sum_i^I p_{i,a,ps}}{I}$ denote the sum of employed wages among workes aged a and the sum of pension received by retired workers, respectively. Note that, for sake of simplificty, the balance equation for the pension system excludes the existence of buffer fund (Holzmann and Palmer (2006), ch. 7). The second line is obtained by considering that pension contributions $pc_{i,a,ps}$ only come from the pool of employed workers whereas figurative contributions on unemployed workers are neglected, i.e. $pc_{i,a,ps} = (1-\mu_{i,a}) r_{pc,ps} w_{i,a}$. The third line is obtained by aggregating over individuals and recalling equation 3 for steady-state dynamics of unemployment μ_a^*. More importantly, the third line explicit the contribution margins. The extensive margin of pension contributions, measuring how many workers contribute, negatively depends on the level of unemployment withing each cohort aged a. The intensive margin, measuring how much employed workers contribute, directly depends on the sum of wages w_a received by each cohort of workers aged a as well as on the level of the pension contribution rate $r_{pc,ps}$. Together, extensive and intensive margins represents the density of pension contribution (Valdes-Prieto, 2008; Chavez-Bedoya, 2017). Indeed, a further margin can be identified from the structural equation of the pension system balance. This margin represents the length of the active period within which workers contribute if employed and it is given by the difference between the entry age a_{min} and the statutory retirement age a_{ret}. I call this margin *durational*. The lower a_{min}, *vel* the higher a_{ret}, the longer it is. On this point, see also Patriarca (2018) and the analysis therein on the balance sheet effect of an unfunded DC pension regime when life expectancy, retirement age and entry age in the labour market vary by cohort.
Adequacy of pension regimes is evaluated in terms of income maintenance,

inequality and poverty among retirees. Income maintenance is measured as the ratio between the average pension $\bar{p}_{ps}$ and the average one-year-pre-retirement wage among employed workers $\bar{w}_{pret}$:

$$rr_{ps} = \frac{\bar{p}_{ps}}{\bar{w}_{pret}} \tag{5}$$

where $\bar{p}_{ps} = \frac{\sum_{a=a_{ret}}^{a_{max}-1} p_{i,a,ps}}{(a_{max}-a_{ret}-1)I}$. Despite this definition of replacement rate allows to overcome some computational problem when the workers are unemployed just prior to retirement, it is not exempt of criticism. See Borella and Fornero (2009) and Chybalski and Marcinkiewicz (2016) for alternative measures of income maintenance.

Inequality is expressed as income quintile ratio Q_{ps} given by the ratio between the total pension received by the 20% of retirees with the highest pension, P_{ps}^{80}, over the total amount received by the bottom 20%, P_{ps}^{20}:

$$Q_{ps} = \frac{P_{ps}^{80}}{P_{ps}^{20}} \tag{6}$$

Lastly, the incidence of poverty is measured by the head-count ratio H_{ps} given by the share of retirees whose pension below the poverty line L_{ps} defined as 60% of the median value:

$$H_{ps} = \frac{\sum_{a=a_{ret}}^{a_{max}-1} \sum_{i=1}^{I} \mathbf{1}(p_{i,a,ps} < L_{ps})}{(a_{max} - a_{ret} - 1)I} \tag{7}$$

Figure 6 depicts the flow diagram associated to model dynamics.

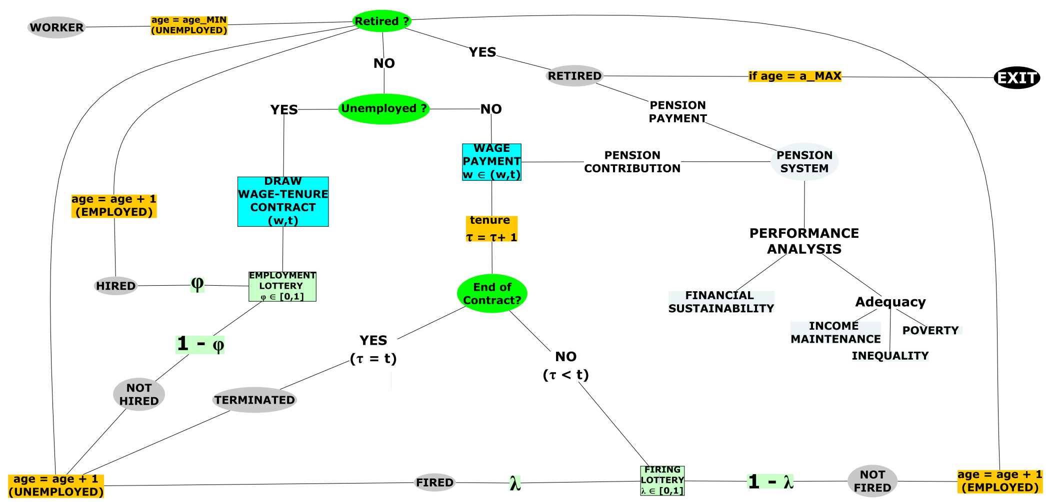


Figure 6: *Flow diagram of the OLG model featuring frictional unemployment, flexible wage-tenure contracts and an unfunded pension system.*

3.2 Pension Regimes

A pension regime ps identifies a rule for pension contributions $pc_{i,a,ps}$ and a formula for pension benefits $p_{i,a_{ret},ps}$. In what follows, each pension regime ps is described in a stylised form, skipping institutional details in order to highlights the main properties. Of course, over decades, their design has been structurally and parametrically reformed in order to cope with *ad hoc* political and financial needs[11].

3.2.1 Standard Pension Regimes: DB and DC

DB and DC pension regimes represent the two main designs for public pension systems. In a DB pension regime, i.e. $ps = DB$, the contribution rule

[11] In this sense, the Italian case is an extraordinary example since pension reforms have been promulgated in almost any legislations. Precisely, out of eighteen legislations (1948-2018), only in the seventh (1976-1979) and in the ninth (1983-1987) the architecture of the Italian pension system had not been reformed.

$pc_{i,a,DB}$ multiplies the current wage $w_{i,a}$ by a homogeneous pension contribution rate r_{pc}, i.e. $r_{pc,DB} = r_{pc}$. In symbols:

$$pc_{i,a,DB} = w_{i,a} r_{pc,DB} = w_{i,a} r_{pc} \tag{8}$$

Note that the whole wage is pensionable, coherently with the focus of the analysis on not-high skilled dependent workers. Instead, national pension systems usually set a yearly ceiling for the pensionable wage beyond which pension contributions are not due (e.g. 101 427 EUR in Italy in 2018). On the other side, DB pension formula computes pension $p_{i,a_{ret},DB}$ as the product between the wage averaged over the last N years and a homogeneous transformation rate $r(r_{DB})$ resulting from accruing each employment year at rate r_{DB}:

$$p_{i,a_{ret},DB} = r(r_{DB}) \left(N^{-1} \sum_{a=a_{ret}-N}^{a_{ret}-1} w_{i,a} \right) \tag{9}$$

Indeed, in some countries, accrual rates are not homogeneous but differentiated by age as in Finland or by income as in Portugal. Besides Finland and Portugal, other countries having a DB pension regime are Austria, Belgium, the Netherlands, Spain, and bureaucrats of the European Commission.

In DC pension regime, i.e. $ps = DC$, firstly described in Castellino (1969), the pension contribution is the same as in DB, that is $pc_{i,a,DC} = pc_{i,a,DB}$. About the pension formula, DC pension is commensurated to the amount of pension contributions cumulated prior to retirement and converted into an annuity. Precisely, DC pension annuity $p_{i,a_{ret},DC}$ is given by the product between accumulated[12] pension system contributions $pc_{i,a,DC}$ and the transformation rate expressing the value of life expectancy at retirement $a_{max} - a_{ret} - 1$:

$$p_{i,a_{ret},DC} = \frac{1}{a_{max} - a_{ret} - 1} \left(\sum_{a=a_{min}}^{a_{ret}-1} pc_{i,a,DC} \right) \tag{10}$$

[12] Indeed, in an unfunded DC, pension contributions are not only accumulated but also (notionally) capitalised at a given notional rate. In his seminal work, Castellino (1969) proposes the average rate of wage growth as indexation variable. Nowadays, different countries have chosen different variables. In Italy, for example, the growth rate of five-year average of nominal GDP is adopted as notional rate together with a one-period-lag in the capitalisation mechanism. Since the indexation mechanism varies across countries, for sake of simplicity, this rate is assumed to be null.

The yearly amount $p_{i,a_{ret},DC}$ needs then to be divided by the numbers of payments in a year, e.g. 12 in case of monthly frequency or 13.5 as in Italy. Besides Italy, countries having a DC pension regime are Sweden, Latvia, Poland and Norway.

3.2.2 Differentiated Pension Regimes: DAC and DTC

Differentiated pension regimes stem from the application of parameters differentiation of an otherwise standard pension regime. In particular, this work presents two variants of DC where the homogeneous contribution rate $r_{pc,ps}$ is differentiated along some relevant dimensions. Differentiation of pension contribution is experimented only within the DC regime since, if applied to DB, it would only increase contribution inflow and so the financial sustainability without affecting performances in terms of adequacy. As argued in Holzmann and Palmer (2006) (ch. 2, condition 2), the relaxation of homogeneity of pension contribution rate for unfunded DC pension regimes is coherent with the condition of constancy (and homogeneity) of contribution rate, that is pension payments are not higher than contributions. As it shall be shown, such a condition is not satisfied in a context of frictional unemployment and flexible contracts. Moreover, the differentiation of pension contribution rate represents an intervention occurring during the accumulation phase, i.e. after contributions are paid and before pensions are computed (Ayuso et al., 2017*a*). At this regard, it is assumed that neither firms nor workers bear the cost of this policy but the public pension system shoulders the burden instead. The dimensions along which pension contributions are differentiated are the age of the worker, called Defined-Age-Contribution (DAC), and the tenure of the contract, called Defined-Tenure-Contribution (DTC).

DAC pension regime, i.e. $ps = DAC$, applies the idea of age specific taxation, firstly proposed by Erosa and Gervais (2002), to the standard design of a DC (Castellino, 1969). The idea of age-differentiated taxation has been applied to labour income taxation (Gervais, 2012; Weinzierl, 2011), employment protection (Cheron et al., 2011) and unemployment subsidies (Michelacci and Ruffo, 2015). Following this tradition, this work presents the first application of an age-specific taxation by differencing pension contribution rate by worker's age. The rationale of this dimension relies on the fact that, not only younger workers experience worse labour market conditions in terms of contracts, but also age is a non-manipulable factor by individuals.

Indicating with $\delta > 0$ the differentiation factor, the pension contribution rule in a DAC pension regime is given by:

$$pc_{i,a,DAC} = w_{i,a} r_{pc,DAC} = w_{i,a} r_{pc} (1+\delta)^{a_{ret}-a} \tag{11}$$

Thus, *ceteris paribus*, the longer the distance from retirement $a_{ret} - a$, the higher the pension contribution rate $r_{pc,DAC}$ because of the magnitude of δ. On the other side, DAC pension $p_{i,a_{ret},DAC}$ shares its pension formula with DC. Hence:

$$p_{i,a_{ret},DAC} = \frac{1}{a_{max} - a_{ret} - 1} \left(\sum_{\alpha=a}^{a_{ret}-1} pc_{i,\alpha,DAC} \right) \tag{12}$$

The structure of DTC pension regime, i.e. $ps = DTC$, closely mimics that of DAC with the tenure of contract being now the differentiation variable for the contribution rate. The rationale relies on the fact that workers employed in contracts with shorter tenure experience a lower probabilities of moving from temporary to permanent positions (Gagliarducci, 2005), receive less employer-funded training than permanent workers (Fouarge et al., 2012) and suffer from a wage penalty (Bosio, 2014). Overall, their conditions in the labour market lower the internal rate of return associated to the pension system compared to workers with a more stable career. Thus, their disadvantaged status in the labour market impact on their status after retirement. Similar to DAC, pension contribution $pc_{i,a,DTC}$ paid by the $i-$th worker when aged a and employed with contract $(w,t)_{i,a}$ is defined as:

$$pc_{i,a,DTC} = w_{i,a} r_{pc,DTC} = w_{i,a} r_{pc} (1+\delta)^{t_{i,a}} \tag{13}$$

Accordingly, the lower the contract tenure $t_{i,a}$, the higher the pension contribution accumulated by the worker during that employment spell.
As in DC and DAC pension regimes, DTC pension formula is expressed as:

$$p_{i,a,DTC} = \frac{1}{a_{max} - a_{ret} - 1} \left(\sum_{\alpha=a}^{a_{ret}-1} pc_{i,\alpha,DTC} \right) \tag{14}$$

Concluding, it is worth noting that a standard DC is a special case with $\delta = 0$. Viceversa, the higher the value of δ, the more pronounced is the impact of differentiation on pension contribution profiles.

3.3 Model Calibration

A reasonable calibration of model parameters is obtained from external sources. The model is simulated for 1200 ticks at monthly frequency, i.e. a century. Size of each cohort I is set to 100. Initial age a_{min} at which workers enter the labour market is set to 25 so to consider workers whose human capital is already formed (Antolin and Stewart, 2009; Antolin and Payet, 2011; Olshansky et al., 2012; Belloni and Maccheroni, 2013). Retirement age a_{ret} is set to 65, coherently with the literature on life expectancy heterogeneity and pension systems (De Freitas et al., 2011; Ayuso et al., 2017*b*,*a*; Holzmann et al., 2017; Ayuso et al., 2018) as well as with empirical data. Exit age a_{max} is set to 85 as postulated by (Fries, 1980). Accordingly, the resulting life expectancy at retirement, i.e. the length of the post-retirement period, is $a_{max} - a_{ret} = 20$ years (Kitao et al., 2017; Lallo and Raitano, 2018; De Nardi et al., 2018).

Concerning the labour market, values for job arrival and separation probabilities are $\phi = 0.9$ and $\lambda = 0.1$ so to introduce a minimal deviation from an otherwise absorbing employment state and to focus on the role of contract termination instead. The tenure-specific separation probability is specified as a power function[13], i.e. $\lambda_{i,a}(\lambda, t_{i,a}) = \lambda_i^t, a$. Minimum and maximum wage w_{min} and w_{max} are set to 500 and 2500 respectively, so to limit the analysis to not-highly skilled dependent workers (e.g. blue collars). The probability density function for wage f_W is specified as a symmetric $f_W = \beta(2,2)$ despite it is empirically grounded and theoretically proved that the employed wage distribution is positively skewed (Decreuse and Zylberberg, 2011; Tejada, 2017). Indeed, despite symmetric distributions have null skewness by definition, the functional specification of a $\beta(2,2)$ is dictated by the possibility to parametrically increase its skewness by raising its second parameter[14]. Contract tenures are drawn according to a discrete uniform distribution f_T,

[13] This functional specification aims to mimic the fact that workers employed in more flexible contracts, i.e. with shorter tenure, experience more frequent job interruptions. Note that the assumption of inter-independence betweeen contract components does not allow to generate any positive association between tenure of contract and corresponding level of wage. If this positive alignement is introduced, then the model, together with the assumption of tenure-decreasing job separation rates, would be able in principle to deliver the negative correlation between wage and separations. The model of Jung and Kuhn (2018) is the first who is able to reproduce such a empirical feature.

[14] For example, a Normal distribution does not allow to do so unless it is specified in its generalised skewed version formulated by Azzalini (1985).

with minimal tenure equals to 1 period and the maximum tenure reflecting the maximal employability of a worker aged a, i.e. $a_{ret} - a - 1$, which reduces once when retirement is closer.
Pension parameters are calibrated having as reference the Italian case. The pension contribution rate is set to 33% (Belloni and Maccheroni, 2013). For DB pension regime, time window N over which the reference wage is computed is set to 20 years. The accrual rate r_{DB} is 2% per year of employment (Mazzaferro et al., 2012; Belloni et al., 2013; Raitano, 2017), which is also not too far from the 2.2% reported by Brown and Weisbenner (2014) for U.S. and from the $[2 - 2.3]$% reported for Portugal by Bravo and Herce (2017). For the DC pension regime, the transformation coefficient $\frac{1}{a_{max} - a_{ret} - 1}$ is equal to $\frac{12}{1020-780-1} = 0.0502$, which is close to the mean coefficient of 0.0523 computed by Belloni and Maccheroni (2013) over legislated and forecasted values for Italy. For the differentiated pension regimes DAC and DTC, the differentiation factor δ is arbitrarily set to 0.25%. Table 1 summarises calibrated values.

Symbol	**Description**	**Value**
	Time Frequency	Monthly
I	*Workers per Cohort*	100
a_{min}	*Entry Age* (years)	300 (25)
a_{ret}	*Retirement Age* (years)	780 (65)
a_{max}	*Exit Age* (years)	1020 (85)
ϕ	*Job Arrival probability*	0.9
λ	*Job Separation probability*	0.1
w_{min}	*Wage - Lower Bound*	500
w_{max}	*Wage - Upper Bound*	2500
$f_W(\cdot)$	*Wage - Pdf*	$\beta(2,2)$
$f_{T,a}(\cdot)$	*Tenure - Pdf*	$U_d(1, a_{ret} - a - 1)$
r_{pc}	*Pension Contribution Rate*	0.33
N	*DB - Pensionable Wage Time Window* (years)	240 (20)
r_{DB}	*DB - Accrual Rate* (yearly)	0.02
δ	*DAC/DTC - Differentiation Factor*	0.0025

Table 1: *Baseline Calibration for model parameters.*

The model described before and calibrated according to the value above represents the baseline scenario. As commonly done in the modelling literature, a sensitivity analysis of model dynamics to unit changes in parameters is provided in appendix A. Other scenarios, alternative to the baseline, are also constructed and commented in appendix B together with alternative functional specifications for the tenure-specific separation probability in the sub-appendix B.9.

4 Results

This section reports results from model simulation run in NetLogo 6.0.3, a multi-agent programmable modeling environment (Wilensky, 1999). Model outcomes are averaged over last sixty periods, i.e. 5 years. Despite arbitrary, this choice relies on the fact that model dynamics is stationary. Accordingly, any time-length can be selected as being equivalently informative once the burning period is excluded from the computational window.
Results reported in this section include flexible labour careers (4.1), age profile of unemployment and its independent components (4.2), the distribution of employment by wage and tenure classes (4.3), the distribution of pensions by income classes and performances of pension regimes in terms of financial sustainability and adequacy (4.4). Other outcomes are provided in appendix C to empirically validate the demographic and labour market modules.

4.1 Flexible Labour Careers

The model presented in section 3 produces flexible labour careers. These endogenous labour careers features unemployment spells due to not being hired when unemployed, being fired when employed or leave when the contract terminates. As shown by figure 7, this implies gaps in terms of pension contribution along workers' careers if, as assumed, no figurative contributions are considered during unemployment spells. Associated pension contribution profiles in the standard DB and DC regimes coincide for a given level of wage. While those in differentiated pension regimes DAC and DTC are different since DAC profile is higher during the early stage of working life, i.e. for lower ages, whereas DTC profile is higher when workers approach to retirement since drawn contract tenures are lower because of residual age-distance to retirement of older workers. In fact, as equation 2 shows, the individual dynamics implies a higher unemployment risk for workers close to retirement since contracts with shorter duration are offered. In this sense offered contracts are flexible, since they can be perfectly adapted to the employability of workers once the hiring firm observes the age of the worker.

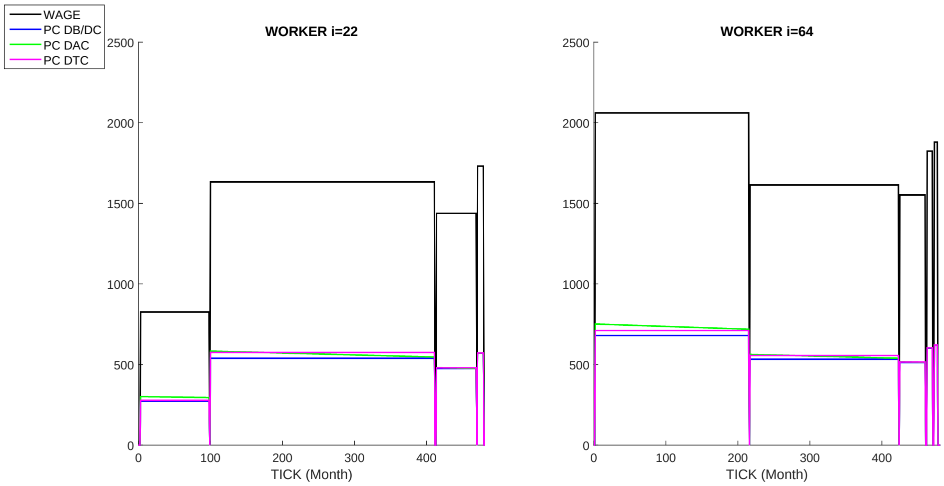


Figure 7: *Labour careers of two generic workers (monetary units).*

In aggregate terms, flexible labour careers features dispersion in terms of employment spells and employed tenure as reported in table 2. Statistics show that the distribution of employment spells is symmetric, i.e. mean equals median, and barely dispersed. Instead, the employed tenure distribution is positively skewed, i.e. the mean is greater than the median, and highly dispersed.

	Statistics		
	Average	**Median**	**St Deviation**
Employment Spells (years)	39.84	39.83	0.09
Employed Tenure (years)	10.17	7.64	8.8

Table 2: *Average, median and standard deviation of employment spells and employed tenure (years).*

Read together, these statistics show that flexible careers are characterised by around 40 years of accumulated employment spells, but not because employment is longlasting. In fact, employment relations last on average 10 years and they are very heterogenous in terms of duration[15].

[15] The comparison between average years of employment spells and average employed tenure may suggest a dimension to measure the degree of contract flexibility in the economy. Suppose an economy with all contracts lasting one unit of time and workers being

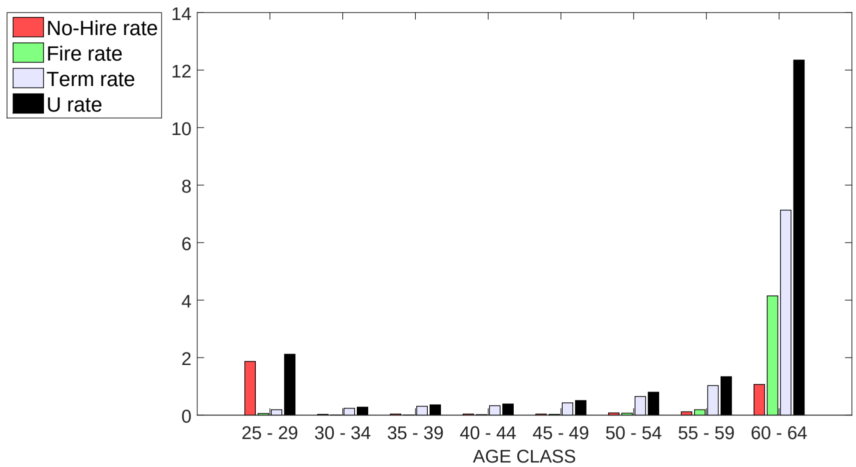
Wage profiles depicted in figure 7 well represent histories of employed workers who experienced job interruptions and changes in their careers as result of flexible contracts and frictional unemployment. Such labour careers are then used as base to retrieve labour and pension statistics. On the contrary, compared to model dynamics, the Neoclassical framework so far adopted to analyse issues related to social security features no labour market frictions nor flexible contracts and, so, it does not allow reproducing gaps in pension contributions nor job changes since employment is an absorbing state.

4.2 Unemployment Age Profile and its Decomposition

Within the literature on life cycle equilibrium unemployment (Cheron et al., 2013; De La Croix et al., 2013; Hairault et al., 2015; Menzio et al., 2016), a standard result is a U-shaped age profiles for unemployment. Middle-aged workers experience better labour market conditions favouring their employability thus reducing their unemployment. While younger and older workers experience higher unemployment rates because of their low experience and their proximity to retirement age, respectively. The assumption of flexible wage-tenure contracts, together with the presence of job arrival and firing probabilities, produces such nonlinear profile as shown by 8.

Besides, figure 8 shows the decomposition of the pool of unemployed into non-hired workers, fired and workers whose contract has terminated. All these components have an U-shaped age profile apart from termination rate which is age-increasing. No-hires aged $25-29$ mainly come from the assumption of entering the economy as unemployed. While for those aged $60-64$, more frequent ins and outs from unemployment makes raises the likelihood of not being hired. The age profile of firing rates is slighlty convex, more pronounced for workers close to retirement who are employed in shorter contracts and, thus, more exposed to the risk of being fired from the ongoing employment relation.

always employed despite they change jobs very frequently. This paradoxical situation would be characterised by a high average for the years of employment spells, since workers are always employed, but the average tenure of employment would be still equal to one. This example can be used intuition to build a contract flexibility index. This exercise is left for future research



	Age Class								
	$25-29$	$30-34$	$35-39$	$40-44$	$45-49$	$50-54$	$55-59$	$60-64$	**TOT**
NO-HIRE RATE	1.87	0.03	0.04	0.04	0.04	0.08	0.12	1.07	**0.41**
FIRE RATE	0.06	0.01	0.01	0.02	0.03	0.07	0.19	4.15	**0.57**
TERMINATION RATE	0.19	0.24	0.31	0.33	0.43	0.65	1.03	7.13	**1.29**
TOT U RATE	2.12	0.28	0.36	0.39	0.51	0.8	1.34	12.35	**2.27**

Figure 8: *Unemployment Components: no-hiring, firing and termination rates by 5-year age class (%).*

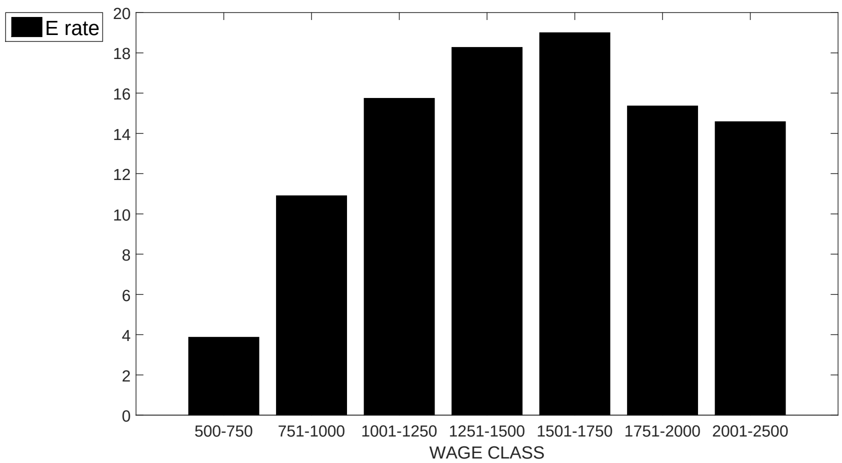
Termination rate is the main component of unemployment, regarding about 57% of the unemployment pool. Its age profile is increasing since workers' ageing lowers their employability and, through this channel, the average lenght of contracts they can receive. It must be remarked that the unemployment rate of workers aged $60-64$ is upwards biased since workers do not retire earlier if unemployed but continue to stay in the labour market. Instead, it is well known that workers close to retirement retire earlier if unemployed (Hairault et al., 2010, 2015). A higher unemployment rate among workers close to retirement could be also compatible with a future, but not futuristic, scenario where automation will displace employment towards younger up-to-date skilled workers (Acemoglu and Restrepo, 2018).
In terms of pensions, a convex age profile of unemployment is detrimental for pension entitlements since pension formula in DB and DC penalises workers if experiencing unemployment spells at the end and at the beginning of their careers, respectively. As shown by Bravo and Herce (2017), DB pension formula penalises workers experiencing employment breaks during the time window over which the reference wage is constructed. See also Peinado and

Serrano (2017) for an empirical estimation of elasticity of pension to unemployment in Spain. In a DC pension regime, inasmuch based on a saving logic, capitalisation factors are higher for earlier contributions. Hence, workers experiencing unemployment at younger ages miss to contribute to their future retirement just when capitalisation factors for pension contributions are the highest. Differentiated pension regimes DAC and DTC are aimed to cope with this problem.

4.3 Employment Profiles

Regarding employment, the age profile is specular to that of unemployment since all workers participate to the labour market. Accordingly, the age profile of the employment rate has an inverted-U shape, featuring lower values for workers aged $25-29$ and $60-64$ whereas there is almost full employment among all age classes in between. More interestingly, model dynamics delivers non-degenerate distributions of the employment rate by wage and tenure classes, which characterises the heterogeneity of workers in terms of labour careers.

The distribution of employment rate by wage classes, depicted in figure 9, features a hump-shaped left-tailed profile stemming from the assumptions of a symmetric $\beta(2,2)$ wage offer distribution and the random assignation mechanism. Its density increases up to the modal class $1501-1750$ and then decreases for the last two classes which are double in terms of size compared to other wage classes.



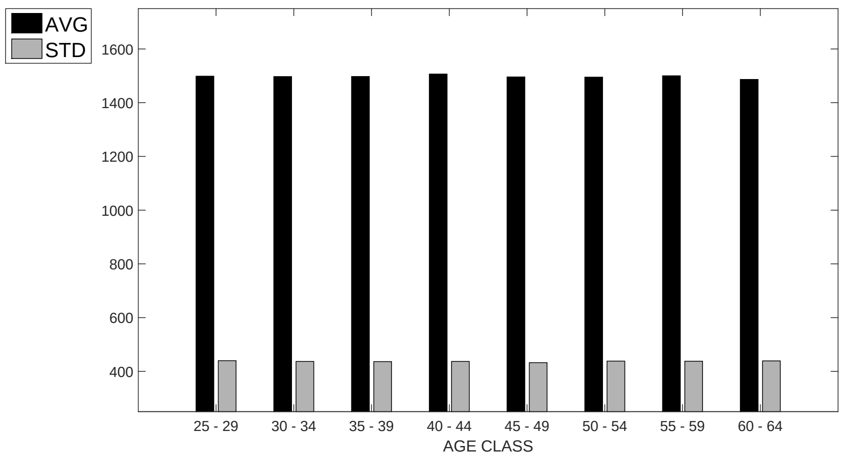
	Wage Class							
	500 − 750	751 − 1000	1001 − 1250	1251 − 1500	1501 − 1750	1751 − 2000	2001 − 2500	**TOT**
E rate (%)	3.87	10.9	15.74	18.27	19	15.35	14.58	**97.73**

Figure 9: *Employment rate by wage classes (%).*

In the literature of equilibrium unemployment and wage dispersion, a hump-shaped right-tailed employed wage distribution is obtained in Decreuse and Zylberberg (2011) in a model of directed search where workers optimally choose search intensity. Also Tejada (2017) reproduces such a shape but in a context of labour market duality. The actual wage distribution plays an important role in the interplay between labour market and pension systems since it is responsible for the intensive margin pension contributions flow. For example, increases in the skewness of the employed wage distribution weaken the intensity of the pension contribution flows. *Sic et simpliciter*, they are a linear combination of paid wages. In this sense, the more the financing scheme of a pension system relies on private financing, the higher would be elasticity of pension contributions inflows to changes in the employed wage distribution[16]. Hence, caution is needed when an offered wage distribution is inserted into the model and, if possible, estimation from empirical data is desirable for improvements along this side.

[16]Regarding the share of private financing of the pension system through pension contributions, Eurostat data for 2011 report that in some EU-15 countries it regards more than 60% (Austria, Belgium, Germany, the Netherlands), in others is between 45 − 55% (Greece, Italy, Portugal, Spain, Sweden) and in other else is less than 30% (Denmark, Ireland).

Moving to the age profile of employed wage, unlike the classical concave profile of Mincer (1974), model outcome reported in figure 10 features a flat profile around the mean. Trivially, the employed wage features wage dispersion in each age class with a corresponding coefficient of variation that is constantly around 0.29.

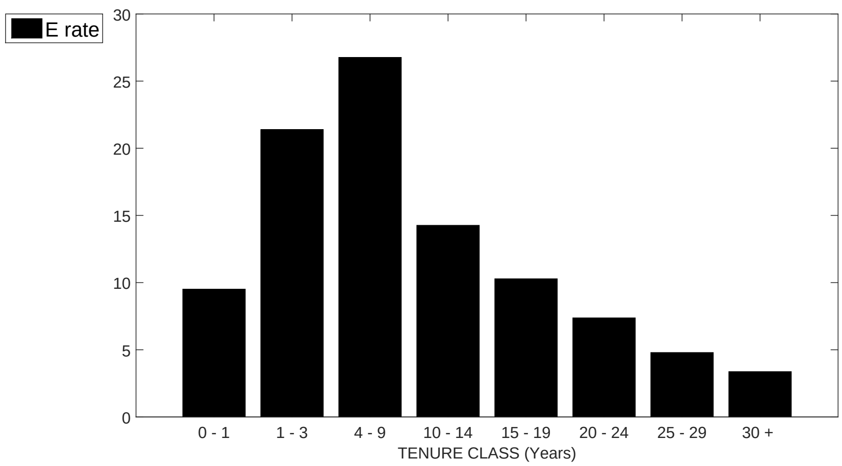


	Age Class								
	25 – 29	30 – 34	35 – 39	40 – 44	45 – 49	50 – 54	55 – 59	60 – 64	**TOT**
Average (monthly)	1498.6	1497.19	1497.43	1506.54	1495.81	1495.01	1500.02	1486.51	**1497.17**
St Deviation (monthly)	439.74	436.82	436.22	436.91	432.39	438.12	437.75	438.92	**437.01**
Coefficient of Variation	0.2934	0.2918	0.2913	0.29	0.2891	0.293	0.2918	0.2953	**0.2919**

Figure 10: *Average, standard deviation and coefficient of variation of wage among employed workers by* $5-$*years age classes (monetary units, monthly).*

Concerning the interplay between labour market and pension systems, a flat age profile of the average wage makes the intensive margin of contribution is constant over the life cycle. In a DB pension regime this means that the reference wage is constant within the time window N and similar to wages outsite this interval. In DC pension regime DC, and also on its differentiated variants DAC and DTC, this means that the average growth rate of accumulated pension assets is constant. For example, the introduction of a seniority factor for wage growth, as well as of on-the-job search, is likely to steepen the wage profile over the life cycle.
Regarding the currently employed tenure, figure 11 reports the distribution of employment rate by tenure classes expressed in years. In doins so, this work is the first which shows such a characteristics within a life cycle model

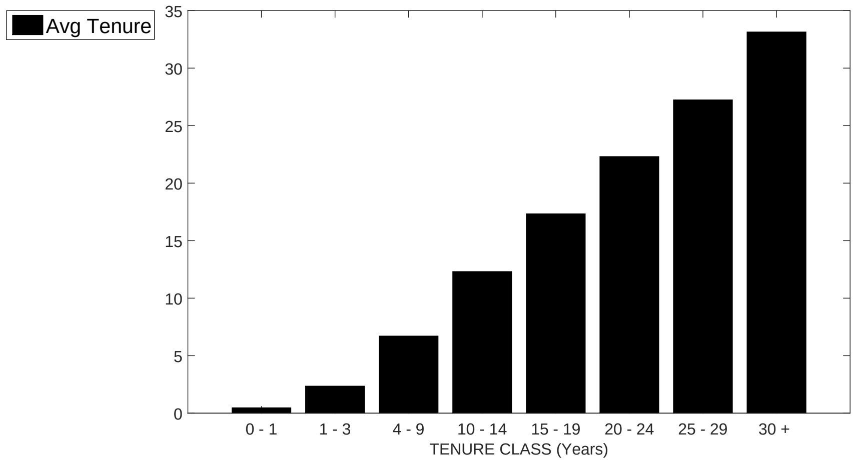
of unemployment. The right-tailed hump-shaped profile is obtained both from the assumption of uniform distribution of offered tenure and from an age-shrinking support coming from the assumption of the age-distance to retirement as driver for offered tenures.



	Tenure Class (years)								
	$0-1$	$1-3$	$4-9$	$10-14$	$15-19$	$20-24$	$25-29$	$30+$	TOT
E rate (%)	9.51	21.39	26.76	14.26	10.28	7.37	4.79	3.37	97.73

Figure 11: *Employment rate by tenure classes (%).*

Note that two third of employed workers are, on average, employed for less than 10 years. Whereas only around 3% are uniterruptedly employed for at least 30 years out of an active period of four decades. The distribution of employment by tenure classes is also reported in terms of average duration in figure 12, which characterises the mean durational margin of employment within each tenure classes.
This perspective allows to note that the average employment duration is centered around the central value of each tenure class but not in the last 30+ where the employment durations are lower than the mean value of that interval. In general, what matters from a modelling perspective is that the distributions of employment rate and the associated average tenure in each tenure class do not degenerate. Instead, as it shall be shown when alternative scenarios are presented in appendix B, a degenerate distribution is a peculiar feature of the Neoclassical paradigm.

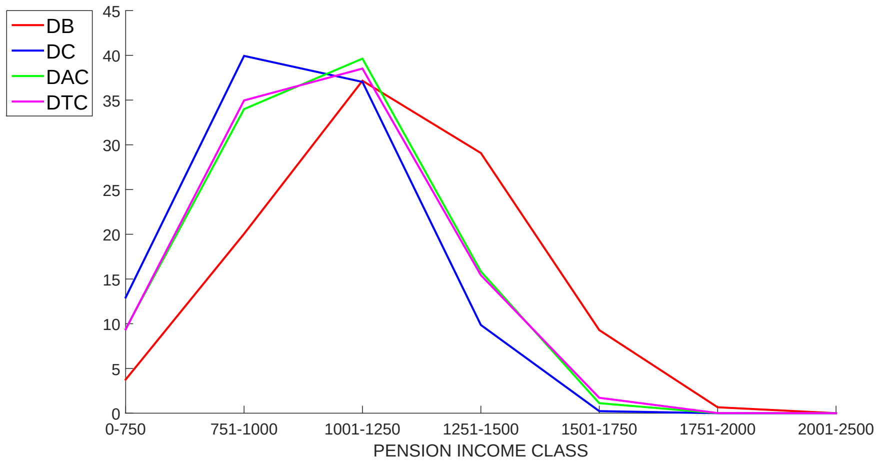


	Tenure Class (years)							
	0 − 1	1 − 3	4 − 9	10 − 14	15 − 19	20 − 24	25 − 29	30+
Avg Tenure (years)	0.4675	2.3493	6.7025	12.31	17.3322	22.3084	27.2374	33.1397

Figure 12: *Distribution of employed tenure by tenure classes (years).*

4.4 Performances of Pension Regimes

Flexible labour careers obtained from model simulation represent the base on which performances of pension regimes are analysed. These represents the main result of this work inasmuch, unlike previous works, labour markets and pension systems can now be analysed in a unified theoretical framework featuring unemployment and flexible wage-tenure contracts over the life cycle. At this regard, figure 13 reports the distribution of pension income in standard DB and DC and differentiated DAC and DTC pension regimes that are endogeneously obtained from labour careers.
In a DB pension regime, the distribution of pension income closely follows the one of employed wage reported in figure 9. The reason lies on DB pension formula, which is based on averaging across wages received during the last phase of workers' career. Instead, the distribution of DC pension income reflects the accumulation of pension contributions paid over the entire labour career.



	Pension Class						
	$0-750$	$751-1000$	$1001-1250$	$1251-1500$	$1501-1750$	$1751-2000$	$2001-2500$
DB	3.76	20.05	37.16	29.08	9.29	0.66	0
DC	12.93	39.94	37.03	9.86	0.23	0	0
DAC	9.41	33.99	39.63	15.85	1.12	0	0
DTC	9.37	34.96	38.52	15.43	1.72	0.01	0

Figure 13: *Distribution of pension income in pension regimes* DB, DC, DAC, DTC *(%).*

DC pension formula is associated to a higher skewness in the pension wealth distribution compared to DB, i.e. DC pension regime is characterised by a higher density for lower values. The first two classes of pension income cumulatively regard around 25% of retirees in DB but more than 50% in DC regime. Similarly, the share of retirees in the last three classes is around 10% under DB and almost zero in DC regime. Differentiated pension regimes DAC and DTC closely follow the distribution of DC pension income, but with a lower skewness. In fact, DAC and DTC pension distribution feature a lower mass in the first two income classes $0-750$ and $751-100$ but higher for income classes $1001-1250$ and $1251-1500$.
Figure 14 reports the dynamics of financial balance B_{ps} defined in equation 4 for each pension regime $ps = DB, DC, DAC, DTC$. The first part of the balance register a surplus since all workers are still active. Afterwards, each pension system starts to pay pensions to retired workers, converging to a long run deficit. In particular, DB pension balance is lower than that of DC since its pension formula is not actuarially fair. In fact, it does not consider how much workers have contributed during their whole labour career but

how long they have been working for. On the contrary, actuarial fairness is a typical feature of DC pension regimes.

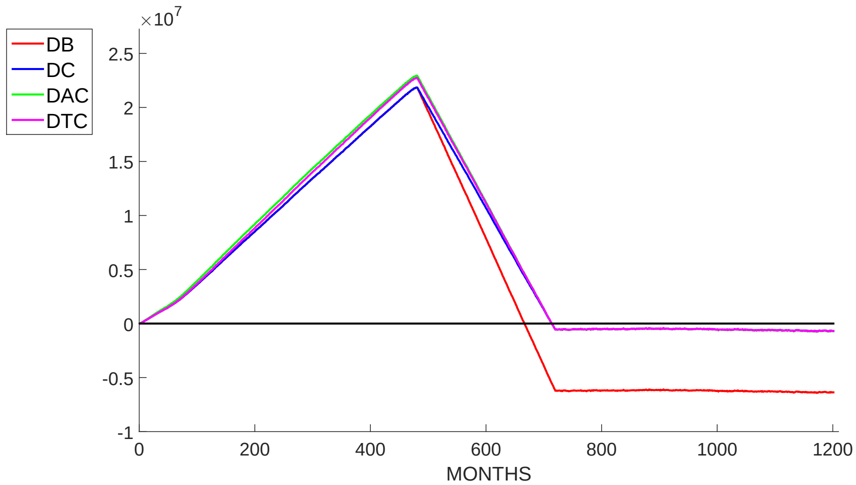


Figure 14: *Dynamics Balance of DB, DC, DAC and DTC pension regimes (tens of millions of monetary units).*

Not surprisingly, all DC-like pension balance register the same level of deficit in the long run. As such, they are more financially sustainable than a standard DB pension system. In terms of adequacy, DB pension regime delivers higher levels of pensions but it does so at the cost of a higher financial deficit compared DC-like pension regimes (by around 10 times). Instead, DAC and DTC pension systems succeed in offering higher pensions compared to a standard DC. DB pension regime also leads to a higher level of inequality and poverty among retirees compared to a standard DC, Whereas differentiated pension regimes DAC and DTC deliver a higher level of inequality compared to standard DB and DC. In terms of poverty, DB registers the higher value followed by DAC, DC and DTC. The result of DTC is desirable since it implies that differencing the pension contribution rate by the tenure of contract alleviates poverty among retirees. Table 3 resumes main results of this work.

	Financial Balance (mln)	Income Maintenance	Inequality	Poverty
DB	-5.0535	79.16	1.826	2.48
DC	-0.4122	66.15	1.8243	2.3
DAC	-0.4157	69.59	1.8321	2.35
DTC	-0.412	69.57	1.8376	2.12

Table 3: *Performances among pension regimes* $ps = DB, DC, DAC, DTC$ *in terms of Financial Balance (mln), Income Maintenance, Inequality and Poverty.*

Qualitatively, results are robust to several structural changes in the model, e.g. introduction of age-threshold for labour market segments, removal of flow probabilities for job arrival ϕ and firing λ, distribution of offered tenure $f_{T,a}$, different specifications for the functional form of tenure-specific separation $\lambda_{i,a}(\lambda, t_{i,a})$. See appendix B for sensibility of model results to these alternative scenarios.

These results are likely to represent an optimistic scenario, that is they can be considered as a lower bound. In particular, since the focus of this work is upon not-high skilled workers with a flat age profile of employed wages, the calibrated range for offered wages produces a lower level of employed wages in the labour market and so of corresponding pensions. Instead, the relative measure of average replacement rate is in line with empirical values of the gross replacement rate reported by OECD for the year 2016, 66.88% in EU-15 and 83.1% in Italy. The calibration of the wage range in the model also influences the dispersion of labour income, which limits the levels of inequality and poverty among retirees produced in the model. At this regard, Eurostat data for the years $2004-2016$ report that the level of inequality is on average at least the double, around 4 in EU-15 and 4.5 in Italy. Similarly, the incidence of poverty post-social transfers, despite decreasing during the period $2004 - 2016$ from around 18% to around 12% both in EU-15 and in Italy, it is extremely high compared to what the model dynamics is able to produce.

5 Conclusions

This is the first work which offers a unified theoretical lifecycle framework to analyse the interplay between labour markets and pension systems through endogeneous labour careers. In particular, it relates unemployment and flexible wage-tenure contracts into a life cycle framework to explicitly characterise extensive and intensive margins of pension contribution flow.

Compared to previous models of frictional unemployment, this work consider two extensions. Firstly, the OLG model featuring short-term lifecycle unemployment is characterised by flexible wage-tenure contracts. As such, unemployment dynamics also depends on the mass of contracts next to expire which determines what has been called termination rate. The higher it is, the shorter the average duration of contracts and, thus, the higher the mass of jobs which terminate. Secondly, the explicit consideration of a post-retirement period allows analysing performances of the two main pension regimes, i.e. DB and DC, as well as two variants of DC based on differentiation of the pension contribution rate with respect to worker's age, i.e. DAC, and to the tenure of the offered contract, i.e. DTC. In such a context, this work studies the effects of flexible employment contracts on performances of pension regimes in terms of financial sustainability and adequacy expressed as income maintenance, inequality and poverty.

Main results show that DC-like pension regimes outperforms a standard DB in terms of financial sustainability, but DB pensions are higher than in other pension regimes. DAC and DTC pensions are, on average, higher pensions than in DC. In terms of inequality, DC outperforms the standard DB as well as its differentiated variants DAC and DTC. The ranking of pension regimes in terms of poverty follows that described for the financial sustainability, i.e. standard DC outperforms DB even thou differentiated pension regimes produce a lower incidence of poverty among pensioners. The sensitivity of model outcomes to changes in parameters is presented in appendix A.

Despite the empirical validation of the model reported in appendix C is satisfactory on several dimensions, e.g. the model perfectly reproduces the distribution of average tenure by age and tenure classes, some extension is needed in order to provide further improvements in terms of model fitting. Some trivial changes in the model are presented in appendix B, where different scenarios are compared to the baseline structure. Regarding possible model extensions, workers' choices and utility are needed to introduce relevant phenomena like long-term unemployment and early retirement. Some

workers' choices regarding labour supply are provided in appendix D under the assumption of risk neutrality. Other important choices like consumption and savings for workers, and vacancy creation and destruction for firms, are left for future research. Also the introduction of a matching technology is of interest in this framework. While the introduction of a production function would be important in order to bring the model economy to a context of general equilibrium. Lastly, inclusion of other types of pension besides old-age can, e.g. disability and poverty, can also be appropriately inserted into modelling framework[17].
In a context of flexible wage-tenure contracts, all these extensions are likely to bring interesting and, hopefully, promising results. The common denominator, on which the aforementioned extensions will be developed, is the adoption of the modelling framework whose the model described in this work is the initial step. And the take-home message is the following. Labour market reforms developed two decades ago, namely the flexibilisation of contracts, have changed the institutional framework on which the analysis of social security systems is based. The introduction of flexible contracts has increased the degree of heterogeneity among workers. When the focus is on pension systems, the impact of work flexibility has reduced both intensive and extensive margins of pension contributions as theoretically shown in this work. Embracing an interconnected perspective, where labour market and pension systems are explicitly inserted into a unified modelling framework, allows to study the implications of alternative designs of an otherwise standard pension systems which is based on the assumption of homogeneity of parameters instead. Hence, the importance of investigating the role of differentiated pensions systems with respect to which differencing the pension contribution rate as in DAC and DTC is just one possible example.

[17] Data from Eurostat reveal that in 2015, in Italy, $15-20\%$ of retirees receive a second type of pension. Also Belgium, Finland, Germany and Portugal show a similar percentage. This share is around $20-25\%$ in France, $10-15\%$ in Austria and Sweden, $5-10\%$ in Greece and Spain and less than 5% in Sweden. Only the Netherlands has a null share of retirees receiving a second pension.

References

Acemoglu, D. and Restrepo, P. (2018), 'Demographics and automation', *NBER Working Paper* (24421).

Aguiar, M., Hurst, E. and Karabarbounis, L. (2013), 'Time use during the great recession', *American Economic Review* **103**(5), 1664–96.

Alvarez, F. and Veracierto, M. (2012), 'Fixed-term employment contracts in an equilibrium search model', *Journal of Economic Theory* **147**(5), 1725–1753.

Antolin, P. and Payet, S. (2011), 'Assessing the labour, financial and demographic risks to retirement income from defined-contribution pensions', *OECD Journal: Financial Market Trends* (2), 189–217.

Antolin, P. and Stewart, F. (2009), 'Private pensions and policy responses to the financial and economic crisis.', *OECD Journal: Financial Market Trends* (1).

Atkinson, J. (1984), 'Manpower strategies for flexible organisations', *Personnel Management* **16**(8), 28–31.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*a*), 'Addressing longevity'heterogeneity in pension scheme design', *Journal of Finance and Economics* **6**(1), 1–21.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*b*), 'On the heterogeneity in longevity among socioeconomic groups: Scope, trends, and implications for earnings-related pension schemes', *Global Journal of Human-Social Science Research* **17**(1), 37–58.

Ayuso, M., Bravo, J. M., Holzmann, R. et al. (2018), 'Getting life expectancy estimates right for pension policy: Period versus cohort approach', *Institute for the Study of Labor (IZA)* (11512).

Azzalini, A. (1985), 'A class of distributions which include the normal ones', *Scandinavian Journal of Statistics* **12**(11512), 171–178.

Batyra, A., de la Croix, D., Pierrard, O. and Sneessens, H. R. (2017), 'Structural changes in the labor market and the rise of early retirement in france and germany', *German Economic Review* .

Belloni, M., Alessie, R., Kalwij, A. and Marinacci, C. (2013), 'Lifetime income and old age mortality risk in italy over two decades', *Demographic Research* **29**, 1261–1298.

Belloni, M. and Maccheroni, C. (2013), 'Actuarial fairness when longevity increases: An evaluation of the italian pension system', *The Geneva Papers on Risk and Insurance-Issues and Practice* **38**(4), 638–674.

Berson, C. and Ferrari, N. (2015), 'Financial incentives and labour market duality', *Labour Economics* **37**, 77–92.

Berton, F. and Garibaldi, P. (2012), 'Workers and firms sorting into temporary jobs', *The Economic Journal* **122**(562), F125–F154.

Bhattacharya, J., Mulligan, C. B. and Reed III, R. R. (2004), 'Labor market search and optimal retirement policy', *Economic Inquiry* **42**(4), 560–571.

Borella, M. and Fornero, E. (2009), 'Adequacy of pension systems in europe: An analysis based on comprehensive replacement rates'.

Borsch-Supan, A. (2000), 'Incentive effects of social security on labour forc participation: evidence in germany and across europe', *Journal of Public Economics* **78**(1), 25–49.

Bosio, G. (2014), 'The implications of temporary jobs on the distribution of wages in in taly: An unconditional ivqte approach', *Labour* **28**(1), 64–86.

Boskin, M. J., Kotlikoff, L. J., Puffert, D. J. and Shoven, J. B. (1987), 'Social security: a financial appraisal across and within generations', *National Tax Journal* **40**(1), 19.

Brauninger, M. (2005), 'Social security, unemployment, and growth', *International Tax and Public Finance* **12**(4), 423–434.

Bravo, J. M. V. and Herce, J. A. (2017), 'On the influence of employment-breaks on pension benefits', *BBVA Working Paper* (19).

Brenzel, H., Gartner, H. and Schnabel, C. (2013), 'Wage posting or wage bargaining? evidence from the employers' side', *Institute for the Study of Labor (IZA)* (7624).

Brown, J. R. and Weisbenner, S. J. (2014), 'Why do individuals choose defined contribution plans? evidence from participants in a large public plan', *Journal of Public Economics* **116**, 35–46.

Burdett, K. and Coles, M. (2003), 'Equilibrium wage-tenure contracts', *Econometrica* **71**(5), 1377–1404.

Burdett, K. and Coles, M. (2010), 'Wage/tenure contracts with heterogeneous firms', *Journal of Economic Theory* **145**(4), 1408–1435.

Cahuc, P., Charlot, O. and Malherbet, F. (2016), 'Explaining the spread of temporary jobs and its impact on labor turnover', *International Economic Review* **57**(2), 533–572.

Castellino, O. (1969), 'Un sistema di pensioni per la vecchiaia commisurate ai versamenti contributivi effettuati e alla dinamica dei redditi medi di lavoro', *Giornale degli Economisti e Annali di Economia* pp. 1–23.

Chavez-Bedoya, L. (2017), 'The effects of risk aversion and density of contribution on comparisons of administrative charges in individual account pension systems', *Journal of Pension Economics and Finance* **16**(1), 1–20.

Cheron, A., Hairault, J.-O. and Langot, F. (2011), 'Age-dependent employment protection', *The Economic Journal* **121**(557), 1477–1504.

Cheron, A., Hairault, J.-O. and Langot, F. (2013), 'Life-cycle equilibrium unemployment', *Journal of Labor Economics* **31**(4), 843–882.

Chybalski, F. and Marcinkiewicz, E. (2016), 'The replacement rate: An imperfect indicator of pension adequacy in cross-country analyses', *Social Indicators Research* **126**(1), 99–117.

Committee, S. P. (2016), 'Review of the social protection performance monitor and developments in social protection policies', *Annual Report 2016* .

Corneo, G. and Marquardt, M. (2000), 'Public pensions, unemployment insurance, and growth', *Journal of Public Economics* **75**(2), 293–311.

Corvers, F., Euwals, R. and de Grip, A. (2012), 'Flexibility of the labour market', *De Economist* **160**(2), 83–87.

De Freitas, N. E. M., Duc, C., Briard, K., Mage, S. and Legendre, B. (2011), 'Career interruptions: how do they impact pension rights?', *The Geneva Papers on Risk and Insurance-Issues and Practice* **36**(3), 440–457.

De La Croix, D., Pierrard, O. and Sneessens, H. R. (2013), 'Aging and pensions in general equilibrium: Labor market imperfections matter', *Journal of Economic Dynamics and Control* **37**(1), 104–124.

De Nardi, M., Fella, G. and Pardo, G. P. (2018), 'Nonlinear household earnings dynamics, self-insurance, and welfare', *National Bureau of Economic Research* (24326).

Decreuse, B. and Zylberberg, A. (2011), 'Search intensity, directed search, and the wage distribution', *Journal of the European Economic Association* **9**(6), 1168–1186.

DellaVigna, S. and Paserman, M. D. (2005), 'Job search and impatience', *Journal of Labor Economics* **23**(3), 527–588.

Di Cintio, M. and Grassi, E. (2015), 'Wage incentive profiles in dual labour markets', *Economica* **82**(328), 790–812.

Erosa, A. and Gervais, M. (2002), 'Optimal taxation in life-cycle economies', *Journal of Economic Theory* **105**(2), 338–369.

European Commission (2018), 'The 2018 ageing report: economic and budgetary projections for eu member states (2016-2070)'.

Faccini, R. (2013), 'Reassessing labour market reforms: temporary contracts as a screening device', *The Economic Journal* **124**(575), 167–200.

Findley, T. S. and Caliendo, F. N. (2009), 'Short horizons, time inconsistency, and optimal social security', *International Tax and Public Finance* **16**(4), 487–513.

Findley, T. S. and Caliendo, F. N. (2014), 'Interacting mechanisms of time inconsistency', *Journal of Economic Psychology* **41**, 68–76.

Findley, T. S. and Caliendo, F. N. (2015), 'Time inconsistency and retirement choice', *Economics Letters* **129**, 4–8.

Fouarge, D., de Grip, A., Smits, W. and de Vries, R. (2012), 'Flexible contracts and human capital investments', *De Economist* **160**(2), 177–195.

Friedberg, L., Owyang, M. and Sinclair, T. (2006), 'Searching for better prospects: Endogenizing falling job tenure and private pension coverage', *The BE Journal of Economic Analysis & Policy* **6**(1), 1–42.

Fries, J. F. (1980), 'Aging, natural death, and the compression of morbidity', *New England Journal of Medicine* **303**(3), 130–135.

Gagliarducci, S. (2005), 'The dynamics of repeated temporary jobs', *Labour Economics* **12**(4), 429–448.

Garibaldi, P. and Wasmer, E. (2005), 'Equilibrium search unemployment, endogenous participation, and labor market flows', *Journal of the European Economic Association* **3**(4), 851–882.

Gervais, M. (2012), 'On the optimality of age-dependent taxes and the progressive us tax system', *Journal of Economic Dynamics and Control* **36**(4), 682–691.

Hairault, J.-O., Langot, F. and Zylberberg, A. (2015), 'Equilibrium unemployment and retirement', *European Economic Review* **79**(C), 37–58.

Hairault, J.-O., Sopraseuth, T. and Langot, F. (2010), 'Distance to retirement and older workers 'employment: The case for delaying the retirement age', *Journal of the European Economic association* **8**(5), 1034–1076.

Hall, R. E. and Krueger, A. B. (2012), 'Evidence on the incidence of wage posting, wage bargaining, and on-the-job search', *American Economic Journal: Macroeconomics* **4**(4), 56–67.

Hinrichs, K. and Jessoula, M. (2012), *Labour market flexibility and pension reforms: Flexible today, secure tomorrow?*, Springer.

Holzmann, R., Alonso-Garcia, J., Labit-Hardy, H. and Villegas, A. M. (2017), Ndc schemes and heterogeneity in longevity: Proposals for redesign, Technical Report 11193.

Holzmann, R. and Palmer, E. (2006), *Pension reform: issues and prospects for non-financial defined contribution (NDC) schemes*, The World Bank.

Jung, P. and Kuhn, M. (2018), 'Earnings losses and labor mobility over the life cycle', *Journal of the European Economic Association* **17**(3), 678–724.

Kahn, L. M. (2012), 'Temporary jobs and job search effort in europe', *Labour Economics* **19**(1), 113–128.

Khaskhoussi, F. (2009), 'Job-search effort, retirement decision and pension reform: A wage bargaining investigation', *Economics Bulletin* **29**(2), 1255–1263.

Kitao, S. (2014), 'A life-cycle model of unemployment and disability insurance', *Journal of Monetary Economics* **68**, 1–18.

Kitao, S., Ljungqvist, L. and Sargent, T. J. (2017), 'A life-cycle model of trans-atlantic employment experiences', *Review of Economic Dynamics* **25**, 320–349.

Laibson, D. (1997), 'Golden eggs and hyperbolic discounting', *The Quarterly Journal of Economics* **112**(2), 443–478.

Lallo, C. and Raitano, M. (2018), 'Life expectancy inequalities in the elderly by socioeconomic status: evidence from italy', *Population health metrics* **16**(1), 7.

Lammers, M. (2014), 'The effects of savings on reservation wages and search effort', *Labour Economics* **27**(C), 83–98.

Low, H., Meghir, C. and Pistaferri, L. (2010), 'Wage risk and employment risk over the life cycle', *American Economic Review* **100**(4), 1432–67.

Low, H. and Pistaferri, L. (2015), 'Disability insurance and the dynamics of the incentive insurance trade-off', *American Economic Review* **105**(10), 2986–3029.

Mazzaferro, C., Morciano, M. and Savegnago, M. (2012), 'Differential mortality and redistribution in the italian notional defined contribution system', *Journal of Pension Economics & Finance* **11**(4), 500–530.

McCall, J. J. (1970), 'Economics of information and job search', *The Quarterly Journal of Economics* **84**(1), 113–126.

Menzio, G., Telyukova, I. A. and Visschers, L. (2016), 'Directed search over the life cycle', *Review of Economic Dynamics* **19**, 38–62.

Michelacci, C. and Ruffo, H. (2015), 'Optimal life cycle unemployment insurance', *American Economic Review* **105**(2), 816–59.

Mincer, J. (1974), 'Schooling, experience, and earnings', *National Bureau of Economic Research* .

Neal, D. (1999), 'The complexity of job mobility among young men', *Journal of Labor Economics* **17**(2), 237–261.

Oeppen, J., Vaupel, J. W. et al. (2002), 'Broken limits to life expectancy', *Science* **296**(5570), 1029–1031.

Olshansky, S. J., Antonucci, T., Berkman, L., Binstock, R. H., Boersch-Supan, A., Cacioppo, J. T., Carnes, B. A., Carstensen, L. L., Fried, L. P., Goldman, D. P. et al. (2012), 'Differences in life expectancy due to race and educational differences are widening, and many may not catch up', *Health Affairs* **31**(8), 1803–1813.

Ono, T. (2007), 'Unemployment dynamics in an olg economy with public pensions', *Economic Theory* **33**(3), 549–577.

Ono, T. (2010), 'Growth and unemployment in an olg economy with public pensions', *Journal of Population Economics* **23**(2), 737–767.

Osuna, V. and Garcia-Perez, J. I. (2015), 'On the effectiveness of short-time work schemes in dual labor markets', *De Economist* **163**(3), 323–351.

Paserman, M. D. (2008), 'Job search and hyperbolic discounting: Structural estimation and policy evaluation', *The Economic Journal* **118**(531), 1418–1452.

Patriarca, F. (2018), 'The effects of aging on notional defined contribution pension systems: A theoretical investigation', *Metroeconomica* **69**(2), 396–408.

Peinado, P. and Serrano, F. (2017), 'Unemployment, wages and pensions', *International Review of Applied Economics* **31**(5), 670–680.

Pissarides, C. A. (2000), *Equilibrium unemployment theory*, MIT press.

Raitano, M. (2017), 'Poveri da giovani, poveri da anziani? prospettive previdenziali e vantaggi della pensione di garanzia', *Social Cohesion Papers* (1).

Rendon, S. (2006), 'Job search and asset accumulation under borrowing constraints', *International Economic Review* **47**(1), 233–263.

Rudanko, L. (2009), 'Labor market dynamics under long-term wage contracting', *Journal of Monetary Economics* **56**(2), 170–183.

Sabatier, M. and Legendre, B. (2017), 'The puzzle of older workers' employment: distance to retirement and health effects', *International Journal of Manpower* **38**(1), 45–61.

Saint-Paul, G. (2009), 'Does the welfare state make older workers unemployable?', *Institute for the Study of Labor (IZA)* (4440).

Shi, S. (2009), 'Directed search for equilibrium wage–tenure contracts', *Econometrica* **77**(2), 561–584.

Smith, E. (2007), 'Limited duration employment', *Review of Economic Dynamics* **10**(3), 444–471.

Sommacal, A. (2006), 'Pension systems and intragenenerational redistribution when labor supply is endogenous', *Oxford Economic Papers* **58**(3), 379–406.

Staubli, S. and Zweimuller, J. (2013), 'Does raising the early retirement age increase employment of older workers?', *Journal of Public Economics* **108**, 17–32.

Stevens, M. (2004), 'Wage-tenure contracts in a frictional labour market: Firms' strategies for recruitment and retention', *The Review of Economic Studies* **71**(2), 535–551.

Tejada, M. M. (2017), 'Dual labor markets and labor protection in an estimated search and matching model', *Labour Economics* **46**(C), 26–46.

Thøgersen, J. (2010), 'Unemployment, public pensions, and capital accumulation: Assessing growth effects of alternative funding strategies', *Journal of Institutional and Theoretical Economics* **166**(3), 502–520.

Tsuyuhara, K. (2016), 'Dynamic contracts with worker mobility via directed on-the-job search', *International Economic Review* **57**(4), 1405–1424.

Valdes-Prieto, S. (2008), 'A theory of contribution density and implications for pension design'.

Weinzierl, M. (2011), 'The surprising power of age-dependent taxes', *The Review of Economic Studies* **78**(4), 1490–1518.

Wilensky, U. (1999), 'Netlogo (and netlogo user manual)'.

Wilthagen, T. and Tros, F. (2004), 'The concept of flexicurity: a new approach to regulating employment and labour markets', *Transfer: European Review of labour and research* **10**(2), 166–186.

A Sensitivity Analysis

This appendix provides a sensitivity analysis of performances of pension regimes with respect to changes in the value of parameters set at the calibration stage for the baseline scenario in table 1. Each model parameter is increased (+) or decreased (−) by a unit if discrete, e.g. age thresholds, or by 1% if continuos, e.g. bounds of wage support. Results in table 4 report the percentage change in performances with respect to the baseline scenario for each model parameters. In doing so, it provides a full picture for the influence that age thresholds, labour market institutions and pension parameters exert on performances of each pension regime in terms of financial sustainability, income maintenance, inequality and poverty among pensioners.

A reduction in the size of cohort I reduces the size of the working population that currently contribute to pay pensions to retirees according to the logic of an unfunded pension system. For the not-actuarially fair DB pension regime, this implies reduction in its financial balance. While for DC-like pension regimes which are actuarially fair, this leads to a sensible improvement. The effect on income maintenance is negative across all pension regimes despite DC, DAC and DTC registers a double intensity compared to DB. Moreover, a reduction in the size of cohorts increases inequality and lower poverty.

Increasing the entry age in the labour market a_{min} lowers the financial balance for all pension regimes since the durational margin of pension contributions reduces. The effect is negative also in terms of income maintenance. Instead, inequality and poverty raises.

A higher retirement age a_{ret} improves the financial sustainability of all pension systems despite at a different intensity, which is substaintially higher for DB compared to DC-like pension regimes. Raising the retirement age has also a positive effect on the level of pensions, especially in DC-like pension regimes, and increases inequality and poverty, in particular for DB. Raising the statutory retirement age exerts a positive effects also on unemployment. In fact, out of the table, increasing a_{ret} by one unit reduces the total unemployment by 2.91% and by 15.08% among those workers aged $60 - 64$[18].

Raises in the exit age a_{max} drammatically lowers the sustainability of DB pension regime, implying that provide correct estimates of life expectancy at

[18] This result is coherent with empirical findings in the literature. For example, Staubli and Zweimuller (2013) finds that in Austria raising the early retirement age from 60 to 62 for men and from 55 to 58.25 for women increased employmenet by 9.75% among men and by 11% among women. See also references therein.

retirement, as well as frequently update their values, is of utmost importance especially for DB pension regimes (Ayuso et al., 2018). On the contrary, in DC-like pension regimes, since their pension formulas explicitly keep into account the value of longevity at retirement, the adjustment is automatic. In fact, *ceteris paribus*, a higher life exptectancy at retirement implies a lower pension as confirmed by lower replacement rates. The effect on inequality is less clear across pension regimes, while poverty reduces in both standard and differentiated pension regimes.

Moving to the effect of changes in flow probabilities, lowering the job arrival probability ϕ reduces worksens the financial balance of pension regimes as well as their performances in terms of income maintenance. Inequality among retirees raises together with poverty, especially among DC-like pension regimes. Instead, increasing the separation probability λ improves the financial balance in all pension regimes, especially that of DC, DAC and DTC. Instead, performances in terms of adequacy are worse since increases in λ lower the average replacement rates and raise inequality and poverty among pensioners.

Regarding the wage space, increases in the minimum wage w_{min} lowers the financial balance across all pension regimes. This means that the beneficial effect that this change exerts on the intensive margin of pension contribution flow is offset by the corresponding increases in pension payments. In terms of adequacy, as expected, the average replacement rates remain unaltered but the levels inequality and poverty reduce. On the contrary, a positive change in the maximum wage w_{max} has a different impact on the financial sustainability of pension systems. While this is negative for DB, it is massively large and positive for DC-like pension regimes. This may suggest that the institutional ceiling imposed on the level of pensionable wage represents somehow a negative factor for the financial sustainability of pension systems[19]. It is also worth to note that a higher w_{max} raises inequality and poverty among retirees, especially for DB, since the variability of offered wages is larger.

Regarding the change in the minimum tenure t_{min} from 1 to 2 months, this is beneficial for the financial balance of all pension systems, especially of DC-like pension regimes. Instead, the effect on income maintenance is negative and has the same intensity across all pension regimes. Instead, raising t_{min}

[19]For example, one could consider to impose a cap not during the contribution phase, i.e. in terms of pensionable wage, but on pensions themselves. The experiment of this design is left for future research.

increases the level of inequality but lowers the incidence of poverty among retirees especially under the DB regime. Similar to increases in the retirement age, raises in the minimum tenure of contracts exerts a positive effect inasmuch it reduces the total unemployment by 2.65% and, since they are the most affected by contract flexibility, by 4% among workers aged $60-64$. Concluding with parameters characterising wage-tenure contracts, the model allows considering also the sensitivity to changes in the skewness of the offered wage distribution through an increase in the second shape parameter of the β distribution. Increasing the density of the wage distribution for lower values has a positive effects on the financial balance of DB, but reduces that of DC-like pension regimes. Such a change also lowers the average replacement rates and the level of poverty among pensioners across all pension regimes, but it increases the level of inequality.

Concerning changes in parameters of pension systems, a raise in the contribution rate r_{pc} has a positive effect on the financial balance of DB while its adequacy performances are not affected. Instead, a 1% positive change of r_{pc} reduces the financial balance and increase the average replacement rate of DC, DAC and DTC by the same percentage. Less clear are the effects on the level of inequality and poverty.

Focusing on parameters of DB pension regime, changes in the pensionable wage time window N have slightly negative effect on its financial balance since pensions are slightly higher as reported by the positive change in terms of average replacement rate. The effect on the level of inequality and the incidence of poverty are both negative, instead. The effects of a lower accrual rate r_{DB} are exactly of opposite sign. That is, the financial balance is sounder beacuse the level of pensions is lower, but also inequality and poverty levels increase even thou to a lower extent.

The last parameter considered is the differentiation factor δ, characterising differentiatiated DC pension regimes DAC and DTC. A 1% increase in its value lowers their balance in the long run but raises the average level of pension even thou by a lower percentage. The elasticity of pension inequality with respect to changes in δ is negative in DAC but positive in DTC pension regime. The effect on poverty is negative for both.

Overall, table 4 shows the innovative content of this work compared to previous studies on pensions since labour market forces affect performances of pension systems. Improvements apart, it can be a valid starting point to provide a comprehensive tool to pension policy makers like the Social Protection Performance Monitor dashboard (Committee, 2016).

	Financial Balance (mln)				Income Maintenance (%)				Inequality (%)				Poverty (%)			
	DB	DC	DAC	DTC	DB	DC	DAC	DTC	DB	DC	DAC	DTC	DB	DC	DAC	DTC
BASE	-5.0535	-0.4122	-0.4157	-0.412	79.16	66.15	69.59	69.57	1.86	1.8243	1.8321	1.8376	2.48	2.3	2.35	2.12
Cohort Size - I (99, -)	-0.11	14.76	15.29	16.08	-0.52	-0.97	-0.98	-0.98	0.44	0.55	0.39	0.72	-5.37	-0.57	-1.12	-1.14
Entry Age - a_{min} (26, +)	-0.27	-22.3	-23.63	-24.36	-2.81	-2.88	-3	-3	1.65	2.02	1.94	2.08	6.78	16.84	17.74	16.03
Retirement Age - a_{ret} (66, +)	27.05	1.23	1.15	0.33	2.04	7.5	7.64	7.56	2.12	1.46	1.33	1.49	28.25	25.43	24.53	25.11
Exit Age - a_{max} (86, +)	-28	0.56	0.63	1.09	-0.01	-4.79	-4.79	-4.8	0.03	-0.19	-0.01	0.15	-0.3	-1.38	-1	-1.77
Job Arrival probability - ϕ (0.891, -)	-1.88	-13.17	-13.84	-14.3	-0.12	-0.25	-0.25	-0.25	0.09	0.14	-0.01	0.16	0.74	5.52	5.12	5.17
Job Separation probability - λ (0.101, +)	0.2	5.63	6.16	5.45	-0.93	-1.03	-1.03	-1.02	0.34	0.46	0.32	0.64	0.92	1.94	1.37	1.21
Min Wage - w_{min} (505, +)	-0.17	-0.16	-0.18	-0.2	0	0	0	0	-0.25	-0.38	-0.13	-0.14	-1.47	-2.49	-2.14	-2.93
Max Wage - w_{max} (2525, +)	-2.62	70.33	69.41	68.13	0.86	-0.53	-0.57	0.38	9.87	3.38	3.02	2.95	72.56	20.96	18.72	12.78
Min Tenure - t_{min} (3, +)	2.03	20.88	21.26	21.27	-0.68	-0.64	-0.64	-0.63	1.12	1.13	0.99	1.01	-10.41	-6.07	-6.28	-8.81
Skewness of Wage Distribution - f_W ($\beta(2,3)$,+)	12.53	-3.24	-4.26	-3.7	-0.5	-0.4	-0.39	-0.37	0.76	0.83	0.48	0.88	-33.29	-34.51	-33.93	-40.8
Pension Contribution rate - r_{pc} (0.3333, +)	4.63	-1.02	-0.97	-0.97	0	1.01	1	1	0	-0.16	-0.21	0.05	0	0.24	-0.09	0.12
DB Pensionable Wage Time Window - N (21, +)	-0.24	-	-	-	0.04	-	-	-	-0.04	-	-	-	-0.32	-	-	-
DB Accrual Rate - r_{DB} (0.198, -)	5.59	-	-	-	-1	-	-	-	0.06	-	-	-	0.05	-	-	-
DAC/DTC - Differentiation Factor δ (0.002525, +)	-	-	-0.13	-0.1	-	-	0.05	0.05	-	-	-0.19	0.21	-	-	-0.33	-0.44

Table 4: *Sensitivity analysis of performances of pension regimes DB, DC, DAC and DTC in the baseline scenario (percentage changes) to changes in model parameters (value, sign of change).*

B Alternative Scenarios

This section provides a comparative analysis of model outcomes in the Baseline scenario (*BASE*), as calibrated in table 1, with alternative scenarios. Each scenario stems from the relaxation of a single assumption characterising the structure of the model.
The aim of this section is to show the implications of different settings regarding the labour market environment. In what follows, each alternative scenario is described in details and implications are described. Results are provided in a tabular format at the end of this section together with the corresponding empirical profiles.

B.1 Young and Old Segments (*Y/O SEG*)

In scenario *Y/O SEG*, the labour market is segmented into Young (Y) and Old (O) workers. This scenario experiments the idea that Young, as unexperienced new entrants, face different labour market conditions[20]. Other works in the literature of frictional unemployment focus on the differential conditions experienced by workers during the first phase of their labour careers. For example, the work of Neal (1999) analyses the job mobility among young workers. The lifecycle model of Kitao et al. (2017) introduces a first phase in which workers are less experienced, lasting on average 3 years, in order to catch a higher churning rate.
At the calibration step, the Y/O age-threshold a_{old} is set to 30 years[21]. Each segment $j = Y, O$ features a specific job arrival and separation probability $\phi_j < \phi_O$ and $\lambda_j > \lambda_O$, with $\phi_j = 0.8$ and $\lambda_Y = 0.2$, while ϕ_O and λ_O remain unaltered with respect to baseline scenario *BASE*. Similarly, the wage distribution $f_{j,W}$ is positively skewed for $j = Y$, i.e. $f_{Y,W} \sim \beta(2, 5)$, and remain symmetric for $j = O$, i.e. $f_{Y,O} \sim \beta(2, 2)$. Lastly, the maximal tenure of contract parametrised by $t_{j,max}$, is set to 36 for $j = Y$ and equals to the age-distance to retirement for $j = O$, i.e. $t_{O,max} = a_{ret} - a - 1$.

[20]The author acknowledges that age discrimination practices in the labour market are prohibited in the Europe Union (2000/78/EC) since December 2003. In Italy, age discrimination is explicitly regulated by the Law Decree 216/2003. This notwithstanding, in real workd, worker's experience is used a dimension to circumvent the prohibition age discrimination. See also Menzio et al. (2016) for a similar comment.

[21]Following Boskin et al. (1987), the age-threshold a_{old} can be also interpreted as the average marriage age beyond which workers are employed in more stable career patterns

Compared to scenario *BASE*, the demographic module remains unchanged since, *sic et simpliciter*, the labour market segmentation does not alter the distribution of population by age groups.
Labour careers remain unchanged in terms of mean and median years of employment spells even if the skewness reduces and their dispersion increases (table 7). While statistics for the employed tenure are lower (table 8). The total unemployment rate almost doubles, since there is more unemployment among workers aged $25-54$ (table 9). Specifically, workers aged $25-29$ and, even thou to a lesser extent, $30-34$ are characterised by a higher rate of unemployment (table 10). This effect allows to obtain a more marked U-age profile since especially firing and termination rates increase (table 11). Specularly, the level of employment is lower among workers aged $25-54$ (table 12), in particular among those aged $25-34$ (table 13). Regarding the employed wage, the rate of employed workers earning less than 1250 monetary units increases (table 14). Accordingly, the average level of wage reduces, dispersion and coefficient of variation raises but the age gap is now negative (table 15). In fact, this scenario is the only one able to produce an increasingly concave profile by age (table 16). The distribution of employment rate across tenure classes sees an increase of workers employed for less than three years, whereas less than 1% is employed for more than thirty (table 17). In terms of employment share, nearly 40% of workers are employed for less than two years (table 18). Disaggregated by 5-years age groups, the effect of the presence of the Y/O segment on the distribution of employment by tenure classes is more evident (table 19). Regarding the average tenure of employment, the mean duration increases across all tenure classes but reduces in the class 30+ years (table 20). Actually, compared to other alternative scenarios, scenario *NO SEG* delivers the lowest average duration in the tenure class 10+ years (table 21). In particular, workers aged less than 40 miss from the tenure class 10+ years (table 22). Regarding the level of inequaliy and poverty, the first statistics raises (table 23). Whereas poverty rate, with a lower poverty line, raises among workers aged $25-54$ but decreases in among those in the age group $55-64$ (table 24).
Concerning pension statistics, the yearly average increases for DB but decreases for DC-like pension regimes (table 25). The pension income distribution in DB remains unchanged, while in DC-like pension regimes it reduces its skewness (table 26). In ters of performances, financial balance and income maintenance decrease in all pension regimes. Inequality and poverty raises in DB but decreases in DC, DAC and DTC pension regimes (table 27).

B.2 Reduce the Entry Age (*MIN AGE 15*)

Scenario *MIN AGE 15* lowers the entry age in the labour market to 15 years, i.e. $a_{min} = 15$. Unlike the scenario *BASE* where $a_{min} = 25$, this demographic change allows to adjust the comparison with empirical data which are based on such a larger age structure of population. Accordingly, labour careers starts a decade before.

Compared to scenario *BASE*, scenario *MIN AGE 15* is the only setting among the alternative scenarios considered that has an impact on the demographic structure of the economy. As expected, the fitting of the model to empirical data is improved in terms of structure of population across all 5−years age classes (table 5). Accordingly, while median age and old-age dependency ratio lowers, the share of population in working raises (table 6). Regarding labour market statistics, average and median years of employment spells raises and coincide but their dispersion remains unchanged (table 7). Instead, all statistics characterising of the distribution of years of employed tenure increase (table 8). In terms of unemployment, total rate and the rate among workers aged $25 - 54$ decreases whereas it raises for older workers (table 9). The lower level of unemployment regards workers aged $25 - 29$ and $50 - 54$ while it is higher in all other age 5-years age classes (table 10). In particular, this reduction comes from a lower rate of no-hiring, firing and termination (table 11). On the other side, the employment rate is higher but not within the age class $55-64$ (table 12). Specifically, the age group $60-64$ shows a slightly lower employment rate (table 13). About the distribution of employent rate by wage, the mass of employed workers increases in all classes but not in the central wage class $1000 - 1750$ (table 14). The average level of wage remains the same but its dispersion increases and so the corresponding coefficient of variation, while the age gap is nearly nil (table 15). This result is confirmed also when the distribution of wage statistics by age is considered (table 16). As expected, a lower the entry age a_{min} increases the rate of employment for tenure classes of 15+ years (table 17). In fact, the employment share in the tenure class of 10+ years is higher (table 18). As expected, this scenario is the only one that deliver a positive share of employment in the tenure class 10+ years among workers $25 - 34$ (table 19). Also in terms of average employed tenure, this alternative scenario delivers the highest duration of employment in the tenure class 30+ years (table 20). But compared to the data, model outcome in the tenure class 10+ years is about one year higher (table 21). Disaggregate by age, this bias comes from

the pool of employed workers aged $30-54$ (table 22). The level of in-work inequality is slightly higher than in scenario *BASE*, but still lower if compared to the empirical counterparts for EU-15 and for Italy (table 23).With a slightly higher poverty line, the level of poverty among employed workers is the highest across scenarios within the age group $25-54$ but it remains low among workers aged $55-64$ (table 24).
Corresponding pension profiles are characterised by a higher average level of pensions across all pension regimes (table 25). In terms of pension income distribution, this trnaslates into a higher dispersion and a lower skewness (table 26). Finally, performances of pension regimes improves the financial sustainability only of DC and DAC. In terms of adequacy, pension average replacement rates are higher in all pension regimes. But also pension inequality and, even more, poverty increase (table 27).

B.3 Silent flow probabilities (*NO FLOW*)

Scenario *NO FLOW* highlights the role of contract termination, a novel friction in the frictional models of labour market. In this scenario, the natural termination of contracts becomes the only source of unemployment. This is obtained by removing uncertainty from the hiring process, i.e. $\phi = 1$, and the possibility to separate a worker from an ongoing contract, i.e. $\lambda = 0$.
Compared to the scenario *BASE*, also this alternative calibration does not impact on the demographic module of the model economy.
In the labour market module, instead, number of years of employment spells is higher but its distribution degenerates (table 7). While the distribution of years of employed tenure is the same as in scenario *BASE*, i.e. negatively skewed and highly dispersed (table 8). As expected, the total level of unemployment decreases and so it does in age classes $25-54$ and $55-64$ (table 9). The same is true if unemployment rate is disaggregated by 5-years age classes (table 10). Abstracting from the assumption of entering the economy as such, all of unemployment only comes from the termination rate of flexible contracts which has an age increasing profile (table 11). This reflects on a very high rate of employment, especially among workers aged $25-54$ for which the termination rate has a lower impact compared to those aged $55-64$ (table 12). In fact, the distribution of employment by 5-years age classes is decreasing (table 13). Regarding the distribution of employment rate by wage classes, compared to scenario *BASE*, no significative difference emerges (table 14). In fact, employed wage statistics are the same included

the age gap (table 15). This is true also if results are disaggregated by 5-years age classes (table 16). Also the distribution of employment rate by tenure classes does not significantly differ, meaning that flow probabilities, as calibrated in scenario *BASE*, do not play a relevant role (table 17). They have a tenure-decreasing impact, i.e. only for lower tenure classes, as emerging from the distribution of employment share (table 18). This is also confirmed when results are disaggregated by 5-years age groups (table 19). Also in terms of average duration of employment there no differences across tenure classes (tables 20, 21 and 22). Also in the case of in-work inequality, the situation is unaltered (table 23). On the contrary, some effect is exerted in terms of poverty since the incidence among workers aged $25 - 54$ is lower (table 24). Moving the comparison to the pension module, the removal of flow probabilities, rendering careers less flexible, increase the average level of pensions across all pension regimes (table 25). Compared to scenario *BASE*, the distributions of pension income is unchanged in DB but slighlty reduces its skewness in DC-like pension regimes since there is a shift from the income class $500-1000$ to that $10001-1500$ (table 26). All these affect performances of pension systems by lowering the financial balance, slightly increasing income maintenance only in DB but not in DC-like pension regimes. Whereas inequality and poverty are lower across all pension regimes (table 27).

B.4 *NO FLOW* with Poisson tenures (*NO FLOW PT*)

Scenario *NO FLOW PT* is identical to scenario *NO FLOW* described above with the difference that the distribution of offered contract tenures is assumed to be a Poisson defined on the same support $[1, a_{ret} - a - 1]$, i.e. $f_{T,a} \sim \mathcal{P}(\cdot)$. Since the Poisson distribution has a high mean (e.g. 20), it is well approximated by a Normal. Accordingly, with no loss of generality, the reader can easily refer to this scenario as the one where offered contract tenure are normally, i.e. mean-variance, distributed. The distribution of tenures becomes a Poisson only when workers are closer to the retirement age because the support shrinks towards lower values. As it shall be shown, this scenario can be assimilated to scenario NEOCLASS (described next) where workers aged $60 - 64$ receive flexible contracts.

Like other alternative scenarios different from *MIN AGE 15*, by construction, *NO FLOW PT* has no impact on the demographic outcomes of the model.

Within the labour market module, compared to scenario *BASE*, workers' careers are characterised by a non-degenerate distribution of years of employment spells centered to the whole duration of the active part of their life cycle with a very low variability (table 7). This translates to a distribution of years of employed tenure with a relatively higher mean, median and standard deviation (table 8). Regarding unemployment statistics, a much lower rate regards not only the total population but also workers aged $25-54$ and $55-64$ (table 9). Only workers aged $25-29$ and those aged $60-64$ show a positive rate of unemployment (table 10). In fact, besides the assumption of unemployment as initial state for those aged $25-29$, termination of contracts acts only for the oldest group of workers (table 11). Specularly, employment is almost full for the whole population apart from workers aged $25-29$ and $60-64$ (tables 12 and 13). No particular effect is exerted on the distribution of employment rate by wage classes (table 14). While the average level of wage does not change particularly, there is a higher level of dispersion, and so a higher coefficient of variation, which leads to a slightly negative age gap (table 15). In fact, the average wage among employed workers aged $60-64$ is higher (table 16). Regarding the tenured employment rate, it is substantially higher starting from the tenure class $15-19$ onwards (table 17). This is confirmed by the extremely higher share of workers employed for at least ten years (table 18). This renders the distribution of employment rate by age and tenure classes degenerate apart among workers aged $25-29$, limited to the tenure class $3-4$ years, and those aged $60-64$ (table 19). The distribution of average employed tenure dominates that in scenario BASE for all tenure classes but not the infrannual class which has the same duration (table 20). In particular, scenario BASE share the same employment length in the infrannual interval $0.5-1$ year (table 21). Also in this alternative scenario, the distribution of average employed tenure by tenure classes degenerates for all age groups but not for the age group $25-29$, for tenure classes lower than five years, and $60-64$, from the tenure class $0.5-1$ year onwards (table 22). The level of in-work inequality is slighlty higher compared tot hat produced in the scenario *BASE* (table 23). In terms of poverty among employed workers, the incidence is higher in both age groups $25-54$ and $55-64$ for an almost equal poverty line (table 24).

Moving to pension statistics, as expected from a less turbolent labour market environment, also this scenario delivers higher average pensions in all regimes (table 25). Associated pension income distributions all show a higher dispersion and a lower skewness. This is true for DB and, to a lesser extent, for DC-like pension regimes. In particular, the skewness of the pension income distribution reduces when one moves from DC to DAC to DTC (table 26).

All pension regimes report a lower financial deficit, with only DB and DTC regimes having a higher average replacement rate. The level of inequality and poverty among retirees is higher in all pension regimes, with the latter adequacy dimension reporting an incidence of around 10% (table 27).

B.5 *NO FLOW* with a single contract (*NEOCLASS*)

Scenario *NEOCLASS* mimics a Neoclassical environment where employment is assumed to be an absorbing state and all contracts are permanent. Accordingly, besides age, employed workers only differ in terms of employed wage. Like scenario *NO FLOW PT*, this scenario is identical to scenario *NO FLOW* with the difference that the distribution of contract tenures degenerates to a single point $[1, a_{ret} - a_{min} - 1]$ representing the maximal age distance to retirement. In a comparative perspective, this alternative scenario is the most interesting since it has been adopted as the reference framework to analyse issues related to pension systems and retirement. With respect to that framework, the models contained in De La Croix et al. (2013), for pension reforms, and Hairault et al. (2015), for retirement, represent an important breaking point inasmuch they allow to analyse the dynamics of welfare policies in old-age within a frictional labour market framework. And this work moves along this direction. As such, a comparison between the scenario *BASE* and a Neoclassical-like scenario is useful to understand the implications of two different modelling frameworks in the analysis of pension systems.

Once again, compared to scenario *BASE*, this alternative scenario maintains the same outcomes within the demographic module.

Concerning the labour market module, the distribution of years of employment spells is degenerate. The mean and, by symmetry, the median values equals the whole length of the period of workers' activity (table 7). The distribution of years of employed tenure is symmetric and, compared to other alternative scenarios, shows the highest mean and dispersion (table 8). As expected, the level of unemployment is minimal, being only due to the assumption of unemployment as worker's entry status (table 9). This results is clearer if one considers the distribution of unemployment rate by 5-years age classes (table 10). Also the disaggregation of unemployment by independent components confirms shows the singularity of this alternative scenario (table 11). Specularly, the employment rate depicts a situation of full employment (table 12). So it does the distribution of employment rate by age groups (table 13). The peculiar distribution of employment rate by wage

classes is somehow purely related to the randomness of the wage offer distribution, which is not affected by the underlying assumptions characterising this alternative scenario . This can be considred the effect of having a single permanent contract drawn at the beginning of the active life cycle (table 14). This notwithstanding, the average level of employed wage is the highest compared to other alternative scenarios together with the level of dispersion. Whereas the associated age gap is null (table 15). In fact, the age profile of epmloyed wage is absolutely flat (table 16). The distribution of employment rate by tenure reports the lowest values tenure classes below fifteen years and highest otherwise (table 17). Instead, in terms of employment share, the tenure class 10+ years shows the highest value among alternative scenarios (table 18). Disaggregated by 5-years age groups, the distribution of employment by tenure classes is degenerate across all ages but not for workers aged $25-29$ which are still affected by the initial spell of unemployment (table 19). The implication of assuming employment as absorbing state for worker's status increases the average duration of employment for all tenure classes (tables 20, 21 and 22). The level of in-work inequality is the lowest compared to all other alternative scenarios (table 23). On the contrary, compared to the scenario *BASE*, the level of in-work poverty is lower among workers aged $25-54$ and remains almost the same among workers aged $55-64$. Whereas the associated poverty line is the highest (table 24).
Finally, the comparison moves to the pension module. Excluding the alternative scenario *MIN AGE 15*, the yearly average pensions reaches the maximum level (table 25). Pension income distributions increase their dispersion and lower their skewness (table 26). More importantly, the performances of pension regimes are peculiar. In terms of financial sustainbility, while DB still registers a deficit, DC-like pension regimes reaches a surplus especially in the standard DC design. Replacement rates maintain the same values reported for all other alternative scenarios. Whereas the level of inequality and poverty among retirees reaches the highest level (table 27).

B.6 Tables of Results across Alternative Scenarios

B.6.1 Alternative Demographic Profiles

	Age Class								
	15 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64	65+
EU-15	18.73	7.11	7.37	7.38	7.17	6.77	6.18	5.62	17.3
ITALY	17.24	7.32	7.74	7.64	7.25	6.75	6.29	5.94	19.7
BASE	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	33.33
MIN AGE 15	21.43	7.14	7.14	7.14	7.14	7.14	7.14	7.14	25.57

Table 5: *Distribution of population share (%) by 5−years age classes in alternative scenarios. Data for EU-15 and Italy are elaborated from Eurostat.*

	Median Age	**Old-Age Dependency Ratio (%)**	**Working Age Population (%)**
EU-15	40	26.14	66.75
ITALY	42	29.82	66.79
BASE	54.96	50	66.67
MIN AGE 15	49.96	40	71.42

Table 6: *Median age, old-age dependency ratio and population in working age (%). For EU-15 and Italy, values for median age and old-age dependency ratio are elaborated from Eurostat data, while values for population in working age are elaborated from OECD data.*

B.7 Alternative Labour Market Profiles

	Scenarios					
	BASE	**SEG**	**MIN AGE 15**	**NO FLOW**	**NO FLOW PT**	**NEOCLASS**
MEAN	39.84	39.7	49.83	39.92	39.98	40
MEDIAN	39.83	39.75	49.83	39.92	40	40
ST DEVIATION	0.09	0.15	0.09	0	0.03	0

Table 7: *Average, median and standard deviation of employment spells (years) across alternative scenarios.*

	Scenarios					
	BASE	**SEG**	**MIN AGE 15**	**NO FLOW**	**NO FLOW PT**	**NEOCLASS**
MEAN	10.17	7.58	12.48	10.08	19.3	20
MEDIAN	7.64	5.03	9.42	7.57	19.25	20
ST DEVIATION	8.8	7.4	10.83	8.78	11.5	11.52

Table 8: *Average, median and standard deviation of employed tenure (years) across alternative scenarios.*

	TOTAL	**AGE** $25-54$	**AGE** $55-64$
EU-15	8.85	7.69	6.18
ITALY	9.4	8.4	4.33
BASE	2.27	0.74	6.84
SEG	3.98	2.81	6.85
MIN AGE 15	1.88	0.62	6.91
NO FLOW	1.68	0.67	4.71
NO FLOW PT	0.39	0.28	0.74
NEOCLASS	0.21	0.28	0

Table 9: *Unemployment rate (%) in all ages and by age groups* $25-54$ *and* $55-64$*. Values for EU-15 and Italy are elaborated from OECD data.*

	Age Class							
	$25-29$	$30-34$	$35-39$	$40-44$	$45-49$	$50-54$	$55-59$	$60-64$
EU-15	11.47	8.55	7.33	6.77	6.41	6.34	6.9	5.79
ITALY	16.56	10.37	7.71	6.39	5.54	4.77	4.5	3.96
BASE	2.12	0.28	0.36	0.39	0.51	0.8	1.34	12.35
SEG	12.72	2.09	0.34	0.42	0.54	0.78	1.33	12.38
MIN AGE 15	0.85	0.29	0.37	0.44	0.57	0.77	1.34	12.49
NO FLOW	1.9	0.25	0.3	0.37	0.46	0.71	1.15	8.27
NO FLOW PT	1.67	0	0	0	0	0	0	1.48
NEOCLASS	1.67	0	0	0	0	0	0	0

Table 10: *Unemployment rate (%) by 5-year age classes. Values for EU-15 and Italy are elaborated from Eurostat data.*

	Age Class								
	$25-29$	$30-34$	$35-39$	$40-44$	$45-49$	$50-54$	$55-59$	$60-64$	*TOT*
NO HIRING RATE (%)									
BASE	1.87	0.03	0.04	0.04	0.04	0.08	0.12	1.07	0.41
SEG	0.43	0.25	0.03	0.04	0.06	0.08	0.13	1.09	0.75
MIN AGE 15	0.64	0.03	0.03	0.05	0.06	0.09	0.14	1.12	0.34
NO FLOW	1.67	0	0	0	0	0	0	0	0.21
NO FLOW PT	1.67	0	0	0	0	0	0	0	0.21
NEOCLASS	1.67	0	0	0	0	0	0	0	0.21
FIRING RATE (%)									
BASE	0.06	0.01	0.01	0.02	0.03	0.07	0.19	4.15	0.57
SEG	6.13	0.32	0.01	0.02	0.04	0.06	0.18	4.15	1.36
MIN AGE 15	0.02	0.01	0.02	0.02	0.04	0.07	0.18	4.19	0.46
NO FLOW	0	0	0	0	0	0	0	0	0
NO FLOW PT	0	0	0	0	0	0	0	0	0
NEOCLASS	0	0	0	0	0	0	0	0	0
TERMINATION RATE (%)									
BASE	0.19	0.24	0.31	0.33	0.43	0.65	1.03	7.13	1.29
SEG	2.29	1.52	0.3	0.36	0.45	0.63	1.02	7.14	1.71
MIN AGE 15	0.56	0.25	0.32	0.37	0.47	0.62	1.03	7.17	1.36
NO FLOW	0.23	0.25	0.3	0.37	0.46	0.71	1.15	8.27	1.47
NO FLOW PT	0	0	0	0	0	0	0	1.48	0.19
NEOCLASS	0	0	0	0	0	0	0	0	0

Table 11: *Comparison of alternative scenarios in terms of unemployment components: no-hiring, firing and termination rates (%) by 5-year age classes.*

	TOTAL	**AGE** $25-54$	**AGE** $55-64$
EU-15	66.48	79.21	49.72
ITALY	57.12	70.86	39.13
BASE	97.73	99.26	93.16
SEG	96.18	97.19	93.15
MIN AGE 15	98.12	99.38	93.09
NO FLOW	98.32	99.33	95.29
NO FLOW PT	99.61	99.72	99.26
NEOCLASS	99.79	99.72	100

Table 12: *Employment rate (%) in all ages and by age groups* $25-54$ *and* $55-64$*. Values for EU-15 and Italy are elaborated from OECD data.*

	Age Class							
	$25-29$	$30-34$	$35-39$	$40-44$	$45-49$	$50-54$	$55-59$	$60-64$
EU-15	74.13	79.52	81.13	81.29	79.71	74.3	60.33	32.04
ITALY	59.14	70.89	74.17	74.46	72.76	66.74	48.56	22.94
BASE	97.88	99.72	99.64	99.61	99.49	99.2	98.66	87.65
SEG	87.28	97.91	99.66	99.58	99.46	99.22	98.67	87.62
MIN AGE 15	99.15	99.71	99.63	99.56	99.43	99.23	98.66	87.51
NO FLOW	98.1	99.75	99.7	99.63	99.54	99.29	98.85	91.73
NO FLOW PT	98.33	100	100	100	100	100	100	98.52
NEOCLASS	98.33	100	100	100	100	100	100	100

Table 13: *Employment rate (%) by 5-year age classes. Values for EU-15 and Italy are elaborated from Eurostat data.*

	Wage Class						
	$500-750$	$751-1000$	$1001-1250$	$1251-1500$	$1501-1750$	$1751-2000$	$2001-2500$
BASE	3.87	10.9	15.74	18.27	19	15.36	14.58
SEG	5.75	13.81	16.53	17.01	16.12	14	12.95
MIN AGE 15	4.71	10.95	15.65	16.8	18.41	15.84	15.74
NO FLOW	3.54	11.27	15.85	18.24	19.32	15.8	14.3
NO FLOW PT	4.45	11.02	16.03	18.08	18.67	15.96	15.41
NEOCLASS	3.99	6.99	17.96	13.97	20.96	15.97	19.96

Table 14: *Employment rate (%) by wage classes across alternative scenarios.*

	AVERAGE WAGE (monthly)	ST DEVIATON	COEFF VAR	WAGE AGE GAP (%)
EU-15	3340.29	-	-	-17.92
ITALY	3059.5	-	-	-24.49
BASE	1497.17	437.01	0.29	0.31
SEG	1441.01	457.27	0.32	-5.7
MIN AGE 15	1502.51	451.32	0.3	0.04
NO FLOW	1500.43	438.02	0.29	0.08
NO FLOW PT	1500.64	447.5	0.3	-0.25
NEOCLASS	1568.6	460.56	0.29	0

Table 15: *Average, standard deviation, coefficient of variation of wage (monthly) and wage age gap ($25-54/55-64$, %) among employed workers across alternative scenarios. Values for EU-15 and Italy are elaborated from OECD data.*

Average	Age Class 25 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64
BASE	1498.6	1497.19	1497.49	1506.54	1495.81	1495.01	1500.02	1486.51
SEG	1076.24	1405.39	1504.61	1497.54	1499.59	1501.84	1504.35	1500.15
MIN AGE 15	1500.79	1503.59	1508.09	1506.32	1502.74	1497.97	1499.82	1504.6
NO FLOW	1500.9	1495.72	1504.67	1507.86	1498.75	1496.74	1501.4	1498.62
NO FLOW PT	1501.89	1501.78	1497.04	1495.62	1497.85	1504.8	1501.73	1505.13
NEOCLASS	1568.6	1568.6	1568.6	1568.6	1568.6	1568.6	1568.6	1568.6
St Deviation								
BASE	439.74	436.82	436.22	436.91	432.39	438.12	437.75	438.92
SEG	324.39	453.5	444.67	446.03	452.27	450.47	446.01	453.51
MIN AGE 15	453.08	454.48	451.8	449.19	444.46	450.15	452.23	451.97
NO FLOW	439.8	436.45	438.62	434.85	432.86	434.28	441.96	445.91
NO FLOW PT	445.25	444.46	447.91	446.45	449.22	451.13	447.36	447.78
NEOCLASS	460.6	460.59	460.59	460.59	460.59	460.59	460.59	460.59
Coeff of Variation								
BASE	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
SEG	0.3	0.32	0.3	0.3	0.3	0.3	0.3	0.3
MIN AGE 15	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NO FLOW	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
NO FLOW PT	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NEOCLASS	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29

Table 16: *Average, standard deviation and coefficient of variation of employed wage (monthly) by* 5−*years age classes across alternative scenarios.*

	Tenure Class (years) 0 − 1	1 − 3	4 − 9	10 − 14	15 − 19	20 − 24	25 − 29	30+
BASE	9.51	21.39	26.76	14.26	10.28	7.37	4.79	3.37
SEG	16.35	26.31	24.28	12.65	8.24	5.14	2.59	0.62
MIN AGE 15	8.12	18.54	24.18	13.99	10.73	7.96	5.79	8.82
NO FLOW	10.15	21.32	26.81	14.42	10.34	7.23	4.7	3.34
NO FLOW PT	3.28	8.27	15.02	12.5	12.5	12.5	12.5	23.04
NEOCLASS	2.29	7.5	15	12.5	12.5	12.5	12.5	25

Table 17: *Employment rate (%) by tenure classes (years) across alternative scenarios.*

	Tenure Class (years)					
	$0-0.5$	$0.5-1$	$1-2$	$3-4$	$5-9$	10+
EU-15	5.81	6.42	13.72	11.97	18.81	39.37
ITALY	4.21	4.44	11.32	11.53	19.99	45.92
BASE	4.93	4.8	15.6	11.91	21.76	41
SEG	8.94	8.06	21.35	11.3	19.93	30.41
MIN AGE 15	4.17	4.11	13.42	10.42	19.69	48.19
NO FLOW	5.25	5.08	15.49	11.75	21.71	40.72
NO FLOW PT	1.59	1.7	5.72	5.11	12.55	73.33
NEOCLASS	1.04	1.25	5.01	5.01	12.53	75.16

Table 18: *Employment share (%) by tenure classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

	Tenure Class (years)					
AGE CLASS: 25-29	$0-0.5$	$0.5-1$	$1-2$	$3-4$	$5-9$	$10+$
EU-15	9.17	10.5	23.59	20.72	25.14	5.18
ITALY	7.62	8.02	21.26	21.57	30.07	6.44
BASE	9.5	11.13	41.89	37.47	0	0
SEG	35.06	26.1	38.84	0	0	0
MIN AGE 15	3.76	4.42	16.84	15.41	33.07	26.5
NO FLOW	9.58	11.24	42.01	37.17	0	0
NO FLOW PT	8.47	10.17	40.68	40.68	0	0
NEOCLASS	8.47	10.17	40.68	40.68	0	0
AGE CLASS: 30-34						
EU-15	5.99	6.92	16.35	16.14	29.72	21.16
ITALY	4.69	4.97	13.69	16.09	31.95	25.63
BASE	1.25	1.47	5.75	5.27	86.26	0
SEG	10.6	14.39	55.87	19.14	0	0
MIN AGE 15	1.27	1.47	5.4	4.78	9.99	77.07
NO FLOW	1.21	1.41	5.49	5.27	86.61	0
NO FLOW PT	0	0	0	0	100	0
NEOCLASS	0	0	0	0	100	0
AGE CLASS: 35-39						
EU-15	4.63	5.33	12.4	12.27	23.58	38.96
ITALY	3.54	3.86	9.68	11.43	25.02	44.18
BASE	1.56	1.8	6.9	6.07	11.87	71.8
SEG	1.49	1.72	6.93	6.93	67.57	0
MIN AGE 15	1.58	1.79	6.62	6.62	10.98	73.36
NO FLOW	1.47	1.78	6.73	6.73	11.9	72.07
NO FLOW PT	0	0	0	0	0	100
NEOCLASS	0	0	0	0	0	100
AGE CLASS: 40-44						
EU-15	3.74	4.29	9.93	9.83	19.05	50.82
ITALY	2.76	2.97	7.64	8.63	18.34	57.94
BASE	1.71	2.02	7.39	6.34	13.93	68.6
SEG	1.81	2.11	7.76	6.52	26.85	54.95
MIN AGE 15	1.87	2.15	8.1	7.04	12.98	67.86
NO FLOW	1.82	2.05	7.51	6.41	13.07	69.13
NO FLOW PT	0	0	0	0	0	100
NEOCLASS	0	0	0	0	0	100
AGE CLASS: 45-49						
EU-15	3.05	3.46	8.05	8.03	15.91	59.56
ITALY	2.14	2.33	5.91	6.82	14.19	67.25
BASE	2.21	2.51	8.58	7.23	13.84	65.62
SEG	2.3	2.59	9.18	7.69	14.15	64.09
MIN AGE 15	2.4	2.71	9.59	7.9	15.59	61.81
NO FLOW	2.23	2.58	9.11	7.61	14.35	64.12
NO FLOW PT	0	0	0	0	0	100
NEOCLASS	0	0	0	0	0	100
AGE CLASS: 50-54						
EU-15	2.49	2.78	6.37	6.57	13.45	57.75
ITALY	1.75	1.73	4.73	5.41	11.24	74
BASE	3.26	3.52	12.26	9.17	15.63	56.17
SEG	3.19	3.57	12.3	9.53	15.7	55.71
MIN AGE 15	3.16	3.48	11.79	9.6	16.57	55.4
NO FLOW	3.4	3.67	12.04	8.81	15.81	56.27
NO FLOW PT	0	0	0	0	0	100
NEOCLASS	0	0	0	0	0	100
AGE CLASS: 55-59						
EU-15	2	2.19	5.16	5.47	11.72	72.13
ITALY	1.56	1.53	4.14	4.69	9.77	77.27
BASE	5.26	5.58	17.56	11.81	17.32	42.46
SEG	5.18	5.49	17.36	11.98	17.65	42.34
MIN AGE 15	5.26	5.61	17.27	11.54	17.62	42.71
NO FLOW	5.4	5.81	17.34	11.89	17.54	42.02
NO FLOW PT	0.01	0	0	0	0	99.99
NEOCLASS	0	0	0	0	0	100
AGE CLASS: 60-64						
EU-15	1.78	1.91	4.85	5.23	11.64	73.22
ITALY	1.67	1.53	4.38	4.69	9.35	77.06
BASE	16.08	11.3	26.2	12.39	13.72	20.31
SEG	15.92	11.17	25.87	12.08	13.92	21.04
MIN AGE 15	16.35	11.51	26.61	11.71	13.35	20.46
NO FLOW	17.92	12.81	24.88	11.18	13.22	19.99
NO FLOW PT	4.41	3.59	5.69	0.71	0.01	85.59
NEOCLASS	0	0	0	0	0	100

Table 19: *Employment share (%) by tenure and age classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

	Tenure Class (years)							
	$0-1$	$1-3$	$4-9$	$10-14$	$15-19$	$20-24$	$25-29$	30+
BASE	0.48	2.35	6.7	12.31	17.33	22.31	27.24	33.14
SEG	0.5	2.16	6.96	12.46	17.46	22.46	27.45	31.88
MIN AGE 15	0.47	2.35	6.74	12.34	17.34	22.33	27.32	36.27
NO FLOW	0.47	2.34	6.71	12.3	17.32	22.31	27.23	33.23
NO FLOW PT	0.48	2.4	6.96	12.46	17.46	22.46	27.46	34.63
NEOCLASS	0.5	2.46	6.96	12.46	17.46	22.46	27.46	34.96

Table 20: *Average employed tenure by tenure classes (years) across alternative scenarios.*

	Tenure Class (years)					
	$0-0.5$	$0.5-1$	$1-2$	$3-4$	$5-9$	10+
EU-15	0.28	0.69	1.69	3.51	6.81	20.15
ITALY	0.29	0.69	1.72	3.52	6.85	20
BASE	0.24	0.7	1.91	3.92	7.28	18.97
SEG	0.24	0.7	1.83	3.92	7.27	17.16
MIN AGE 15	0.24	0.7	1.91	3.92	7.31	21.45
NO FLOW	0.24	0.7	1.9	3.92	7.29	18.9
NO FLOW PT	0.25	0.7	1.92	3.95	7.46	24.59
NEOCLASS	0.25	0.71	1.96	3.96	7.46	24.96

Table 21: *Average employed tenure (years) by tenure classes. Values for EU-15 and Italy are elaborated from OECD data.*

	Tenure Class (years)					
AGE CLASS: 25-29	$0-0.5$	$0.5-1$	$1-2$	$3-4$	$5-9$	10+
EU-15	0.29	0.69	1.69	3.5	6.55	11.17
ITALY	0.29	0.69	1.73	3.51	6.63	11.2
BASE	0.25	0.71	1.94	3.94	0	0
SEG	0.23	0.69	1.59	0	0	0
MIN AGE 15	0.25	0.71	1.95	3.94	7.36	12.36
NO FLOW	0.25	0.71	1.94	3.94	0	0
NO FLOW PT	0.25	0.71	1.96	3.96	0	0
NEOCLASS	0.25	0.71	1.96	3.96	0	0
AGE CLASS: 30-34						
EU-15	0.29	0.7	1.71	3.53	6.87	12.49
ITALY	0.29	0.69	1.74	3.54	6.9	12.51
BASE	0.25	0.71	1.95	3.95	7.34	0
SEG	0.26	0.71	1.89	3.68	0	0
MIN AGE 15	0.25	0.71	1.93	3.94	7.37	16.86
NO FLOW	0.25	0.71	1.95	3.95	7.33	0
NO FLOW PT	0	0	0	0	7.46	0
NEOCLASS	0	0	0	0	7.46	0
AGE CLASS: 35-39						
EU-15	0.29	0.69	1.71	3.53	6.93	14.65
ITALY	0.29	0.69	1.73	3.55	6.98	14.7
BASE	0.25	0.71	1.94	3.94	7.33	12.33
SEG	0.25	0.71	2.02	4.15	6.93	0
MIN AGE 15	0.25	0.71	1.93	3.94	7.33	20.67
NO FLOW	0.25	0.71	1.94	3.94	7.36	12.32
NO FLOW PT	0	0	0	0	0	12.46
NEOCLASS	0	0	0	0	0	12.46
AGE CLASS: 40-44						
EU-15	0.29	0.69	1.71	3.53	6.9	17.47
ITALY	0.29	0.69	1.72	3.54	6.96	17.45
BASE	0.25	0.71	1.92	3.95	7.31	16.65
SEG	0.25	0.71	1.93	3.94	8.3	11.91
MIN AGE 15	0.25	0.71	1.94	3.94	7.23	23.81
NO FLOW	0.25	0.71	1.93	3.93	7.32	16.65
NO FLOW PT	0	0	0	0	0	17.46
NEOCLASS	0	0	0	0	0	17.46
AGE CLASS: 45-49						
EU-15	0.29	0.69	1.71	3.53	6.91	20.44
ITALY	0.28	0.69	1.73	3.54	6.93	20.74
BASE	0.25	0.71	1.92	3.94	7.3	20.14
SEG	0.25	0.71	1.93	3.92	7.31	15.69
MIN AGE 15	0.25	0.71	1.93	3.93	7.31	26.02
NO FLOW	0.25	0.71	1.93	3.93	7.31	20.16
NO FLOW PT	0	0	0	0	0	22.46
NEOCLASS	0	0	0	0	0	22.46
AGE CLASS: 50-54						
EU-15	0.28	0.69	1.71	3.53	6.91	23.35
ITALY	0.28	0.69	1.73	3.54	6.92	23.99
BASE	0.25	0.7	1.92	3.9	7.26	23
SEG	0.25	0.7	1.92	3.91	7.24	19.14
MIN AGE 15	0.25	0.71	1.92	3.92	7.28	27.37
NO FLOW	0.25	0.7	1.91	3.91	7.32	22.79
NO FLOW PT	0	0	0	0	0	27.46
NEOCLASS	0	0	0	0	0	27.46
AGE CLASS: 55-59						
EU-15	0.28	0.69	1.72	3.54	6.94	26.61
ITALY	0.28	0.7	1.74	3.53	6.91	26.26
BASE	0.24	0.7	1.89	3.9	7.14	24.56
SEG	0.24	0.7	1.92	3.9	7.18	21.37
MIN AGE 15	0.25	0.7	1.89	3.9	7.19	27.71
NO FLOW	0.25	0.7	1.88	3.91	7.13	24.38
NO FLOW PT	0	0	0	0	0	32.46
NEOCLASS	0	0	0	0	0	32.46
AGE CLASS: 60-64						
EU-15	0.29	0.7	1.73	3.54	6.96	26.55
ITALY	0.28	0.69	1.75	3.54	6.91	27.72
BASE	0.22	0.7	1.82	3.86	7.06	24.61
SEG	0.22	0.7	1.82	3.86	7.03	22.31
MIN AGE 15	0.22	0.7	1.81	3.84	7.04	26.86
NO FLOW	0.23	0.69	1.8	3.85	7.08	24.57
NO FLOW PT	0	0.69	1.68	3.51	5.25	37.21
NEOCLASS	0	0	0	0	0	37.46

Table 22: *Average employed tenure (years) by tenure and age classes. Values for EU-15 and Italy are elaborated from OECD data.*

	EU-15	ITALY	BASE	SEG	MIN AGE 15	NO FLOW	NO FLOW PT	NEOCLASS
IQR	4.85	6	2.41	2.58	2.48	2.4	2.45	2.37

Table 23: *In-work inequality (income quintile ratio, IQR) across alternative scenarios. Values for EU-15 and Italy are elaborated from Eurostat data.*

	POVERTY LINE	HCR 25-54 (%)	HCR 55-64 (%)
EU-15	-	7.6	7.42
ITALY	-	10.48	7.98
BASE	900.63	7.66	2.48
SEG	853.48	9.02	2
MIN AGE 15	907.77	9.49	2.23
NO FLOW	902.05	7.29	2.48
NO FLOW PT	902.13	7.93	2.6
NEOCLASS	948.9	7.49	2.51

Table 24: *In-work poverty line (monetary units) and poverty rate (Head-Count Ratio, HCR) among employed workers aged* $25-54$ *and* $55-64$ *across alternative scenarios. Values for EU-15 and Italy are elaborated from Eurostat data.*

B.8 Alternative Pension Profiles and Performances

	Scenarios					
	BASE	**SEG**	**MIN AGE 15**	**NO FLOW**	**NO FLOW PT**	**NEOCLASS**
DB	14174.52	14214.31	17742.98	14374.31	14389.55	15020.44
DC	11844.14	11360.07	14389.32	11945.38	11927.5	12443.83
DAC	12459.25	11925.53	15810.32	12564.24	12544.83	13087.75
DTC	12457.32	11809.13	15815.88	12558.45	13154.91	13750.88

Table 25: *Average pension (yearly amount) across alternative scenarios and pension regimes.*

	Pension Income Class						
	$0-750$	$751-1000$	$1001-1250$	$1251-1500$	$1501-1750$	$1751-2000$	$2001-2500$
Scenario: BASE							
DB	3.76	20.05	37.16	29.08	9.29	0.66	0
DC	12.93	39.94	37.03	9.86	0.23	0	0
DAC	9.41	33.99	39.63	15.85	1.12	0	0
DTC	9.37	34.96	38.52	15.43	1.72	0.01	0
Scenario: SEG							
DB	4.3	19.47	35.99	29.45	9.92	0.86	0
DC	14.14	47.37	33.95	4.53	0.01	0	0
DAC	10.33	41.1	39.79	8.65	0.13	0	0
DTC	11.23	43.07	37.29	8.14	0.27	0	0
Scenario: MIN AGE 15							
DB	0.84	5.78	18.01	27.7	27.28	15.49	4.91
DC	2.91	16.25	32.23	32	14.74	1.87	0
DAC	1.84	12.08	27.05	32.59	20.42	5.68	0.34
DTC	1.77	12.19	28.13	31.37	19.46	6.3	0.78
Scenario: NO FLOW							
DB	3.09	18.86	36.14	30.91	10.08	0.93	0
DC	11.9	38.77	38.52	10.55	0.27	0	0
DAC	8.8	32.77	40.66	16.35	1.43	0	0
DTC	8.75	33.75	39.49	16.14	1.86	0	0
Scenario: NO FLOW PT							
DB	11.21	19.74	24.06	22.77	16.78	5.44	0
DC	23.12	27.57	27.33	18.68	3.3	0	0
DAC	19.8	25.39	26.49	20.92	7.4	0	0
DTC	16.6	23.31	25.61	22.5	11.3	0.69	0
Scenario: NEOCLASS							
DB	9.18	19.92	20.22	21.91	19.01	9.76	0
DC	22.13	22.43	26.83	21.93	6.69	0	0
DAC	16.2	23.28	26.73	20.22	13.56	0	0
DTC	12.3	24.95	23.84	22.14	13.93	2.85	0

Table 26: *Comparison of pension income distributions in standard and differentiated pension regimes across alternative scenarios.*

	Financial Balance (mln)				Income Maintenance (RR)				Inequality (IQR)				Poverty (HCR)			
	DB	DC	DAC	DTC	DB	DC	DAC	DTC	DB	DC	DAC	DTC	DB	DC	DAC	DTC
BASE	-5.0535	-0.4122	-0.4157	-0.412	79.16	66.15	69.59	69.57	1.83	1.82	1.83	1.84	2.48	2.3	2.35	2.12
SEG	-6.3574	-0.6727	-0.6996	-0.6796	79.05	63.18	66.32	65.68	1.86	1.73	1.73	1.75	2.76	1.39	1.37	1.28
MIN AGE 15	-6.1486	-0.3655	-0.3675	-0.4143	98.44	82.33	87.72	87.75	1.87	1.85	1.86	1.87	3.08	2.71	2.82	2.51
NO FLOW	-5.2606	-0.423	-0.4306	-0.4307	79.53	66.09	69.51	69.48	1.81	1.81	1.82	1.83	2.24	2.16	2.22	1.91
NO FLOW PT	-4.9826	-0.0791	-0.0079	-0.0085	79.28	65.71	69.11	72.47	2.36	2.41	2.41	2.41	9.33	9.85	9.84	9.79
NEOCLASS	-5.1203	0.0115	0.0014	0.0013	79.8	66.11	69.53	73.05	2.57	2.57	2.57	2.57	9.95	9.59	9.95	9.99

Table 27: *Comparison of performances between DB and DC pension regimes in terms of Financial Balance (in millions of monetary units), Income Maintenance (average replacement rate, RR), Inequality (income-quintile Ratio, IQR) and Poverty (head-count ratio, HCR) and associated Poverty Line across alternative scenarios. Values for EU-15 and Italy are elaborated from Eurostat data.*

B.9 Alternative Tenure-specific Separations

Performances of pension regimes are compared across different specifications for the functional form of the tenure-specific separation probability $\lambda_{i,a}(\lambda, t_{i,a})$ associated to a contract $(w,t)_{i,a}$ of wage $w_{i,a}$ and tenure $t_{i,a}$ received by i-th worker when unemployed and aged a.

In the baseline scenario, the relation between the separation probability λ and the tenure of the drawn contract $t_{i,a}$ is specified as a power function, i.e. $\lambda_{i,a} = \lambda^{t_{i,a}}$, meaning that the probability of job separation is lower for contracts with higher offered tenure and remains constant throughout the employment relation. In the simplest, unconditional, specification it is assumed that $\lambda_{i,a}(\lambda, t_{i,a})$ is constant and does not depend on the tenure of the contract $t_{i,a}$, i.e. $\lambda_{i,a} = \lambda$ for any $t_{i,a} \in [1, a_{ret} - a - 1]$. A tenure-independent separation probability is the classical assumption of frictional models of duality in the labour market, with an exception represented by Alvarez and Veracierto (2012)[22]. The other two alternative functional specifications continue to assume that the tenure-specific separation $\lambda(t_{i,a})$ decreases for higher tenures like in the baseline scenario. Precisely, the second specification is characterised by a tenure-dependent decay in the form of ratio, i.e. $\lambda_{i,a}(\lambda, t_{i,a}) = \lambda/t_{i,a}$. The third alternative specification is similar to the baseline specification with the difference that the probability of separation decreases along with the continuation of the employment relation indexed by $\tau = 1, ..., t_{i,a}$, i.e. $\lambda_{i,a} = \lambda^{\tau}$ (see equation 1).

Figure 15 below depicts the corresponding profiles for a given value of λ. Despite the baseline specification $\lambda^{t_{i,a}}$ and the last specification λ^{τ} graphically coincide, their are different in the way they apply. Unlike the baseline specification, the specification λ^{τ} decreases at any period the employed worker proceeds along the contract ladder induced by the contract (see figure 5). In the baseline scenario, instead, the tenure-decreasing separation probability remains fixed throughout the employment relation.

[22] Despite the model of this work does not explicitly consider firing costs, the resulting profile is qualitatively similar to that obtained in the case of tenure-dependent firing costs proposed by Alvarez and Veracierto (2012), that it is tenure-decreasing. In that work, authors adopt a tenure-dependent dismissal cost specified as a step function taking value zero for those contracts with a certain tenure and positive otherwise.

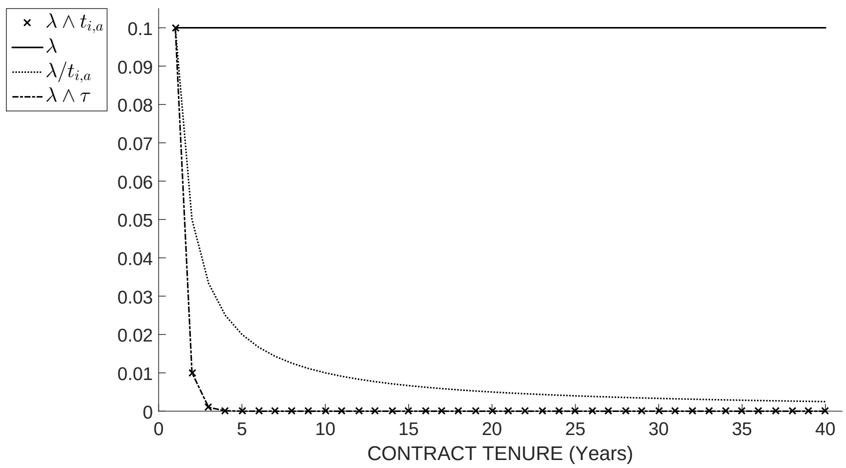


Figure 15: *Functional Specifications for the tenure-specific separation rate for* $\lambda = 0.1$*: baseline* λ^t*, unconditional* λ*, ratio* $\lambda/t_{i,a}$ *and power to current tenure* λ^τ.

Table 28 reports sensitivity results of pension performances across alternative specifications for the tenure-specific separation probability $\lambda_{i,a}$. Overall, one can see that the functional form matters in terms of performances of pension regimes. In particular, the financial sustainability drammatically worsens in all pension regimes when one moves from the baseline specification $\lambda^{t_{i,a}}$ to more frequent separation regimes λ^τ, $\lambda/t_{i,a}$ to unconditional specification λ. Also the relation between frequency of job separation and average replacement rate is negative, since more frequent unemployment spells lowers the level of pension rights, either in terms of a lower cumulated accrual rate in DB pension regime and in DC-like pension regimes through a reduced cumul of pension contributions. On the contrary, more frequent separations reduce the level of inequality and poverty among retirees. This can be confirmed by comparing pension perfomances in the baseline scenario where $\lambda_{i,a} = \lambda^{t_{i,a}}$ with those obtained in the unconditional case where $\lambda_{i,a} = \lambda$, where the latter shows the lowest level of inequality and the absence of poverty among retirees.

Financial Balance (mln)	**Functional Specifications** $\lambda^{t_{i,a}}$	λ	$\lambda/t_{i,a}$	λ^{τ}
DB	-5.0535	-7.0011	-5.2898	-5.197
DC	-0.4122	-2.673	-0.633	-0.4882
DAC	-0.4157	-2.7996	-0.6446	-0.5008
DTC	-0.412	-2.7376	-0.6437	-0.4884
Income Maintenance (RR)				
DB	79.16	77.45	79.08	78.42
DC	66.15	65.34	66.07	65.34
DAC	69.59	68.73	69.5	68.73
DTC	69.57	67.13	69.23	68.67
Inequality (IQR)				
DB	1.83	1.26	1.74	1.84
DC	1.82	1.21	1.70	1.83
DAC	1.83	1.2	1.71	1.84
DTC	1.84	1.2	1.72	1.85
Poverty (HCR)				
DB	2.48	0	1.89	2.66
DC	2.3	0	1.45	2.42
DAC	2.35	0	1.47	2.49
DTC	2.12	0	1.29	2.18

Table 28: *Comparison of performances pension regimes DB, DC, DAC and DTC in terms of Financial Balance (mln), Income Maintenance (average replacement rate, RR), Inequality (income-quintile Ratio, IQR) and Poverty (head-count ratio, HCR) across alternative specifications for the tenure-specific separations.*

Read together, these results suggest interesting empirical relations. According to the sensitivity results presented in table 28, one should find a negative relation, for example, between the index of employment protection and the financial balance of public pension systems. A negative relation should also emerge between employment protection and replacement rates. On the contrary, the sign characterising the relation between frequency of job separations and inequality or poverty is expected to be positive. But, first of all, it would be important to test which tenure-specific separation specification is in place. Needless to say, it is expected that the specification varies across economic sectors of employment, ages and worker's experience since worker's productivity is likely to play an important role in this context. All these empirical questions are left to future research.

C Empirical Validation

This section compares model outcomes with their empirical counterparts provided for EU-15 countries[23], with a particular focus on Italy. Data are extracted from Eurostat and OECD databases and include demographic (C.1) and labour statistics (C.2). For each statistics under comparison, a graphical representation reports the empirical time profile together with the model counterpart. Tabulated results compare the data averaged over the last two decades with corresponding model outcomes unless otherwise specified.

C.1 Demography

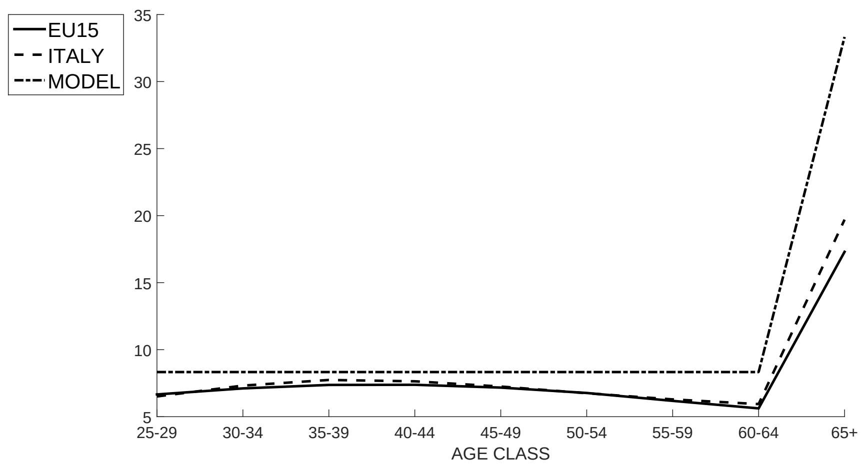
This section compares empirical profiles for EU-15 and for Italy with corresponding model outcomes for the age structure of population (figure 16, median age, old-age dependency ratio, working age population (figure 17) and life expectancy at age 65 (figure 18).

C.1.1 Age Structure of Population

Model dynamics closely replicates the age structure of population averaged over the time period $1997-2016$. As figure 16 shows, for ages $25-54$, the absolute distance between model and data is just 1 p.p. (8% vs 7%) whereas for ages $55-64$ it raises to 2 p.p. (8% vs 6%). For ages 65+ is higher than observed by 16 p.p. and 13 p.p. compared to EU-15 and Italy respectively (33% vs 17% for EU-15 and 20% for Italy, respectively).
Unlike the empirical data, workers belonging to the age class $0-24$ are excluded from the model. This exclusion is responsible for the positive bias between model outcomes and empirical values within the age range $25-64$. In particular, people aged $0-14$ are excluded since they are not allowed to participate into the labour market. A rescaling of the age composition of population excluding this age group is likely to reduce such a bias, even thou to a smaller extent. Instead, the exclusion of workers aged $15-24$ relies on the consideration that those people are likely to be in their educational ages *vel* to be NEETs. However, one of the alternative scenarios considered in appendix B includes this age group into the model by reducing the entry age

[23] Indeed, the number of countries considered in the EU-15 pool is twelve. Ireland, Luxembourg and the United Kingdom are excluded.

a_{min} from 25 to 15. The corresponding outcome confirms that this extension improves the model fitting in terms of the age structure of population.



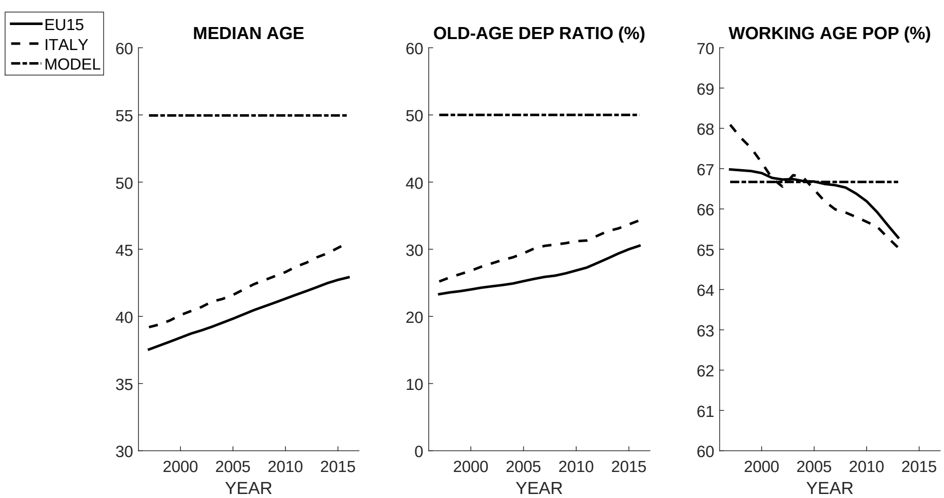
	Age Class								
	25 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64	65+
EU-15	6.66	7.11	7.37	7.38	7.17	6.77	6.18	5.62	17.3
ITALY	6.51	7.32	7.74	7.64	7.25	6.75	6.29	5.94	19.7
MODEL	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	33.33

Figure 16: *Distribution of population by* 5−*years age classes. Values for EU-15 and Italy are elaborated from Eurostat data.*

Note also that the share of population aged 65+ is larger than empirically observed for EU-15 and for Italy. Assuming a greyer economy, i.e. an economy with a greater share of individuals in old-age, might not be a big issue in a context of a gradual ageing. But recalling that by assumption the demographic structure of population influences the aggregate jobs offer in terms of duration of contracts, changes in the age composition of population impact on the distribution of employment by tenure classes. For this reason, it is expected that the model delivers shorter average tenures among the employed population compared to what observed in the data. This demographic bias then translates into higher share of workers employed with shorter tenure. To reduce such bias, the introduction of age-increasing mortality forces, e.g. survival or death probabilities, are needed.

C.1.2 Median Age, Old-Age Dependency Ratio and Population in Working Age

This overpresence of workers aged 65+ is reflected on other demographic statistics depicted in figure 17. These are median age, old-age dependency ratio and the share of population in working age. Empirical values are averaged over the years $1997-2016$.
In the model, the median age of population is 15 and 13 years higher than in EU-15 and in Italy respectively (55 vs 40 for EU-15 and 42 for Italy). The old-age dependency ratio, i.e. the ratio between people aged 65+ over those aged $15-64$, is almost the double compared to what observed in EU-15 (50% vs 26.14%) and in Italy (50% vs 29.81%). Instead, the share of population in working age is two third as in EU-15 (66.75%) and Italy (66.79%). In this case, such a perfect fitting results also from the time-averaging procedure and hides the negative time-trend presented characterising the empirical profile and due to a time-increasing share of the retired population.



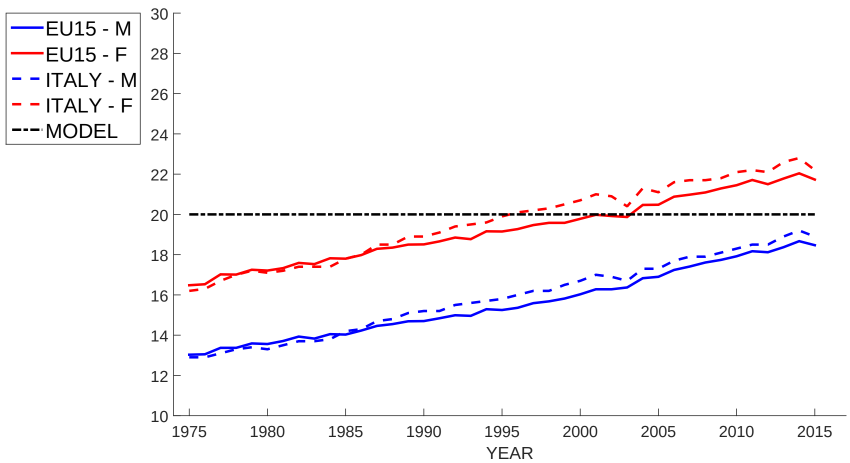
	Median Age	Old-Age Dependency Ratio	Working Age Population
EU-15	40	26.14	66.75
ITALY	42	29.81	66.79
MODEL	55	50	66.67

Figure 17: *Median age (left), old-age dependency ratio (center) and share of population in working age (right). Values for EU-15 and Italy are elaborated from Eurostat data (left and center) and OECD data (right).*

Despite demographic module in the model is characterised by an abundance of old individuals, it remains a valid scenario for the next decades especially if one considers that the old-age dependency ratio is expected to raise above 50% around the year 2050 in Europe Union (European Commission, 2018). Meanwhile, lower the entry age into the economy to 15 years, as done in one of alternative scenarios considered in appendix B, or introducing age-increasing mortality probabilities, as one of the possible model extensions, allows reducing such a ageing gap between model population and the empirical counterpart especially in terms of median age and old-age dependency ratio. Regarding the working share of population and its negative time-trend, it is possible to raise the exit age a_{max} over time. For example, it is possible to couple the age-increasing mortality with the Oeppen's rule of thumb by increasing the maximum age in the model by three months every year (Oeppen et al., 2002). This is left for future research since the model abstracts from population ageing.

C.1.3 Life Expectancy at Retirement

The calibrated value of retirement age $a_{ret} = 65$ and exit age $a_{max} = 85$ produces a value for life expectancy at retirement of 20 years, representing the length of the post-retirement period. Figure 18 shows the evolution of life expectancy at retirement, i.e. at age 65, for males and females for the EU-15 and for Italy over the period $1975 - 2015$. It is possible to see that model outcome is coherent with most recent values reported for EU-15 (18.47 and 21.73) and for Italy (18.9 and 22.2) for males and females, respectively.



	EU-15		**Italy**		**Model**
	Male	Female	Male	Female	
Life Expectancy at age 65 (2015)	18.47	21.73	18.9	22.2	20

Figure 18: *Life expectancy (years) at age* 65 *in year* 2015*. Values for EU-15 and Italy are elaborated from OECD data.*

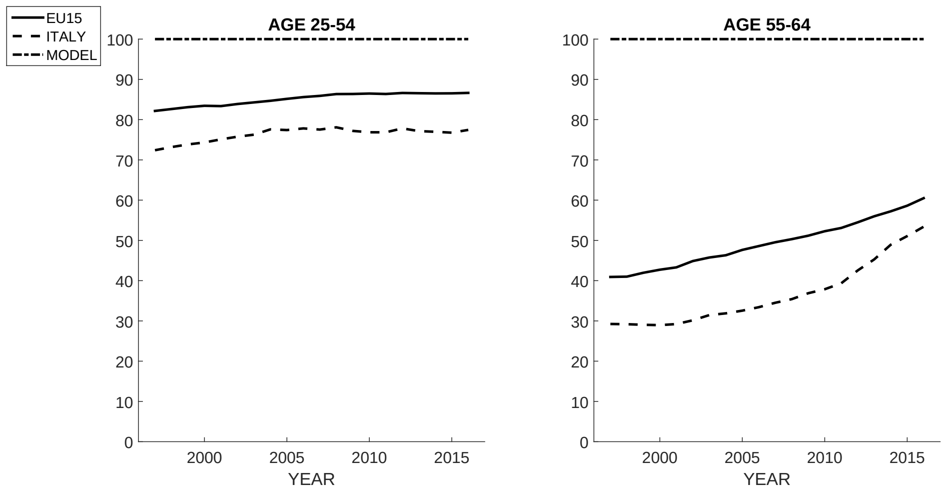
Clearly, the constancy of the value for exit age $a_{max} = 85$ does not allow to capture the positive time-trend observed in the data. As previously said, the stationarity of the model does not consider population ageing. Also in this case, it would be useful to consider that life expectancy at birth has linearly increased by three months since 1840 (Oeppen et al., 2002). Together with the introduction of a mortality force, this consideration may be a way to introduce population ageing in the model economy coherently with what observed in the data. Besides cohort-specific effects, another important aspect not considered by the model is the heterogenity of longevity by socio-economic status like gender, education, geography and income. This phenomenon, which persists and does not decrease over time (Ayuso et al., 2017*b*), affects the actuarial fariness of pension systems especially of DC type. Generated by the application of a homogeneous factor for life expectancy at retirement in the computation of pensions, this phenomenon triggers a tax/-subsidy mechanism favouring those retirees who systematically live longer than imputed at the expenses of those with shorter lives.

C.2 Labour Market

This section compares empirical profiles with corresponding model outcomes for main lifecycle statistics of the labour market. These are participation rates (figure 19), unemployment rate (figures 20, 21 and 22), employment rates (figures 23 and 24), employed wage statistics (figures 25 and 26), employment share (figures 27 and 28) and average employed tenure (figures 29 and 30) by tenure classes, in-work inequality and poverty (figures 31 and 32) and the effective retirement age (figure 33).

C.2.1 Participation

Figure 19 compares labourforce participation in EU-15 and in Italy over $1997-2016$ with the corresponding model outcome. In the model economy, the exclusive consideration of active labourforce implies a full participation of all workers into the labour market. While the entire population in working age is assumed to be active (100%), empirical profiles for individuals aged $25-54$ are lower (85.13% in EU-15 and 76.32% in Italy). This is particularly true for those aged $55-64$ (49.31% in EU-15 and 35.51% in Italy). Participation of workers aged 65+, around 6% in EU-15 and 4% in Italy, is excluded in the model from the assumption of a mandatory retirement age.



	EU-15	ITALY	MODEL
Age 25-54	85.13	76.32	100
Age 55-64	49.31	35.51	100

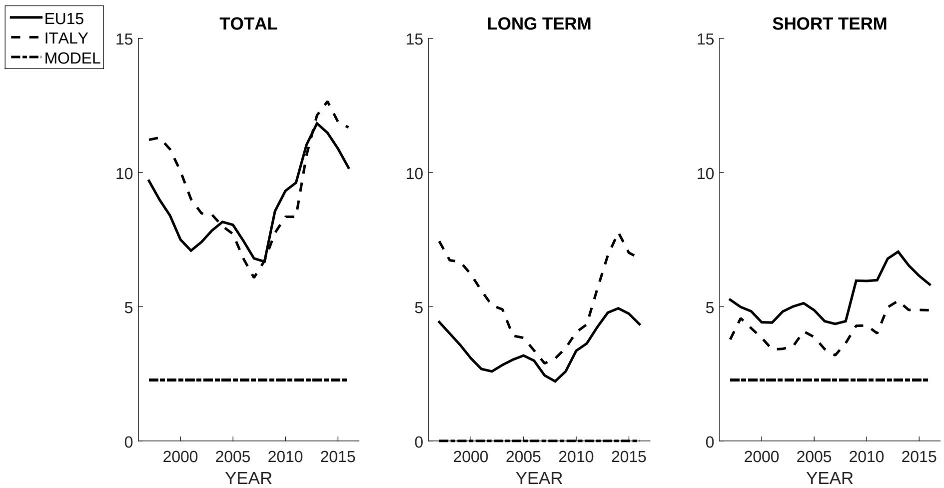
Figure 19: *Participation rate (%) by age classes* $25-54$ *and* $55-64$*. Values for EU-15 and Italy are elaborated from OECD data.*

Indeed, most of frictional labour market models abstract from participation margin since workers are assumed to be either employed or unemployed Pissarides (2000). In order to fill the gap between model outcomes and empirical data, introduction of inactivity status for workers aged $25-54$, e.g. through NEET behaviour and disability status, and those aged $55-64$, through disability and early retirement, would help to reduce the positive bias. At this aim, Garibaldi and Wasmer (2005), seminal in considering participation choices into an equilibrium unemployment framework, is good reference work. Concerning health and disability status, see the works of Kitao (2014) and Low and Pistaferri (2015). Such extensions are left for future research.

C.2.2 Unemployment

Regarding unemployment statistics, figure 20 reports the empirical profiles for the (harmonised) unemployment rate in the short and long term (longer than a year) for the EU-15 for in Italy over $1997-2016$. Model dynamics is able to provide unemployment only in the short run (2.27%), which is however lower than what observed (5.37% in EU-15 and 4.12% in Italy).

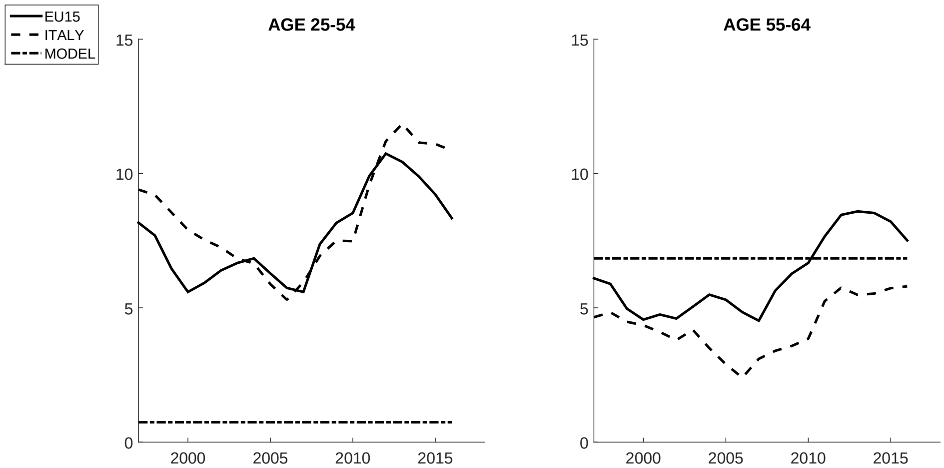
Accordingly, the total unemployment rate is also lower in the model than in the data (8.85% in EU-15 and 9.4% in Italy).



	Unemployment rate (%)		
	TOTAL	**LONG TERM**	**SHORT TERM**
EU-15	8.85	3.48	5.37
ITALY	9.4	5.28	4.12
MODEL	2.27	0	2.27

Figure 20: *Total (left), long term (center), short term (right) unemployment rate (%). Values for EU-15 and Italy are elaborated from OECD data.*

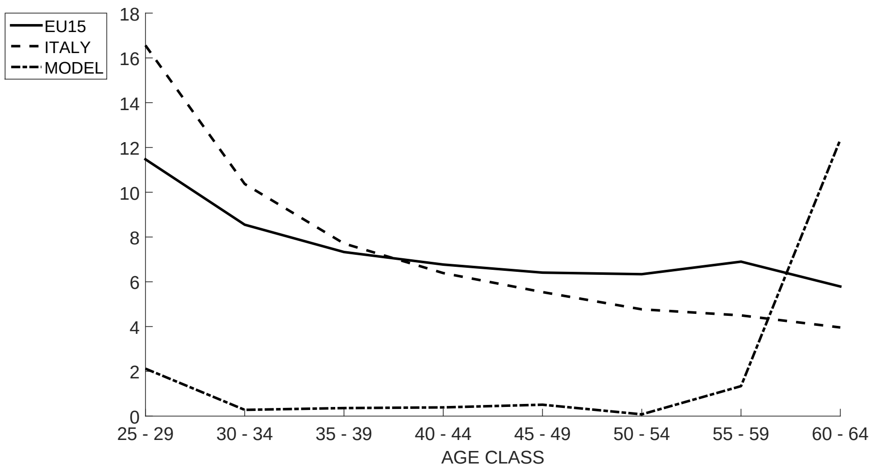
Regarding short term unemployment, the negative bias between model outcomes and empirical values can be reduced, as shown by one of the alternative scenarios presented in appendix B, by considering for younger workers a labour market segment characterised by a lower job finding rate, a higher firing rate and shorter offered tenure contracts. Instead, compared to empirical values (3.48% in EU-15 and 5.28% in Italy), long term unemployment can be obtained by equipping workers with an extensive margin of labour supply. Modelled in the form of reservation wage as in McCall (1970), this is illustrated in appendix D. Trivially, if a lower time frequency is assumed, e.g. quarterly or yearly, long-term unemployment would arise by construction since a unit spell of unemployment would correspond to a longer time. Model assumption regarding unemployed workers are also disaggregated by age. Figure 21 distinguishes between age groups $25-54$ and $55-64$ and reports empirical profiles for EU-15 and for Italy over the period $1998-2017$.



	EU-15	ITALY	MODEL
Age 25-54	7.69	8.4	0.74
Age 55-64	6.18	4.33	6.84

Figure 21: *Unemployment rate (%) by age classes* $25-54$ *(left) and* $55-64$ *(right). Values for EU-15 and Italy are elaborated from OECD data.*

As expected, model dynamics is characterised by a lower profile especially among workers aged $25-54$ (7.69% in EU-15 and 8.4% in Italy) but it is in line with what observed among those aged $55-64$ especially in EU-15 (6.18% and 4.33% in Italy).
A further disaggregation reports unemployment profile by $5-$years age classes for the years $1997-2016$. Figure 22 shows that unemployment exhibits an U-shaped age profile due higher rates among younger workers and those close to retirement. The higher unemployment rates among workers aged $25-29$ is primarily due to the assumption of unemployment as initial state (1.67%). Instead, the convexification of the unemployment age profile for higher ages depicts the distance to retirement effect, due to firms offering shorter contracts to compensate a reduced employability Saint-Paul (2009).



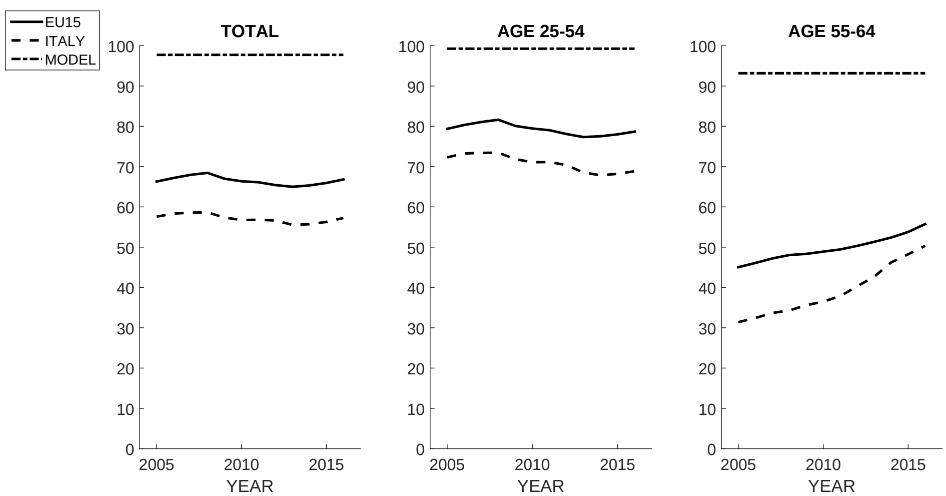
	Age Class							
	25 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64
EU-15	11.47	8.55	7.33	6.77	6.41	6.34	6.9	5.79
ITALY	16.56	10.37	7.71	6.39	5.54	4.47	4.5	3.96
MODEL	2.12	0.28	0.36	0.39	0.51	0.8	1.34	12.35

Figure 22: *Unemployment rate by 5-year age classes (%). Values for EU-15 and Italy are elaborated from Eurostat data.*

From a modelling viewpoint, in a context of one-sided search, the same U-shaped age profile is obtained through an age-increasing work disutility Bhattacharya et al. (2004), an age-increasing search disutility with (single-price) wage bargaining Khaskhoussi (2009); Hairault et al. (2015) or posting Hairault et al. (2010), or as result of an age-decreasing health factor Sabatier and Legendre (2017). But these works limit their analysis to workers aged at most 60 in order to exclude the oldest 5-years age group which is heavily affected by the presence of early retirees.
Besides labour supply choices, disability and early retirement, a further extension that can improve the fitting of the model could be the introduction of a mechanism for vacancy creation over the life cycle with random search as in Cheron et al. (2013) or directed search as in Menzio et al. (2016).

C.2.3 Employment

Employment statistics are crucial in the analysis of the interplay between labour market and pensions since they characterise the extensive and intensive margins of pension contributions as shown in equation 4. Actually they are more important than unemployment, since it serves as labour market state to reproduce gaps in the pension contribution if they are not figuratively credited as assumed in the model.
In the model, since all workers are assumed to participate into the labour market, the situation is specular to that of unemployment describe before. In particular, as shown by figure 23, the total employment rate in the model (97.73%) is higher compared to the corresponding empirical values (66.48% in EU-15 and 57.12% in Italy).

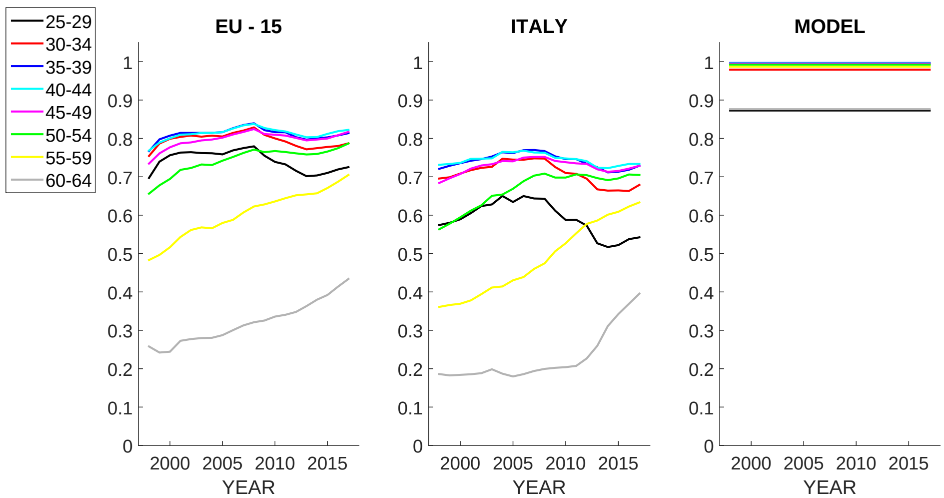


	Age Class		
	TOTAL	**25-54**	**55-64**
EU-15	66.48	79.21	49.72
ITALY	57.12	70.86	39.13
Model	97.73	99.26	93.16

Figure 23: *Employment rate by age classes (%): Total (left),* $25-54$ *(center) and* $55-64$ *(right). Values for EU-15 and Italy are elaborated from OECD data.*

In particular, workers aged $25-54$ enjoy nearly fully employment (99.26%) while it is slighlty lower for those aged $55-64$ (93.16%). Corresponding empirical profiles, averaged over the years $2005-2015$, are much lower in both

age groups (79.21% in EU-15 and 70.86% in Italy for the age group $25-54$, 49.72% in EU-15 and 39.13% in Italy for ages $55-64$).
Disaggregated by 5−years age groups, figure 24 confirms that workers aged $30-59$ are in full employment whereas those aged $25-29$ and $60-64$ are close to it.



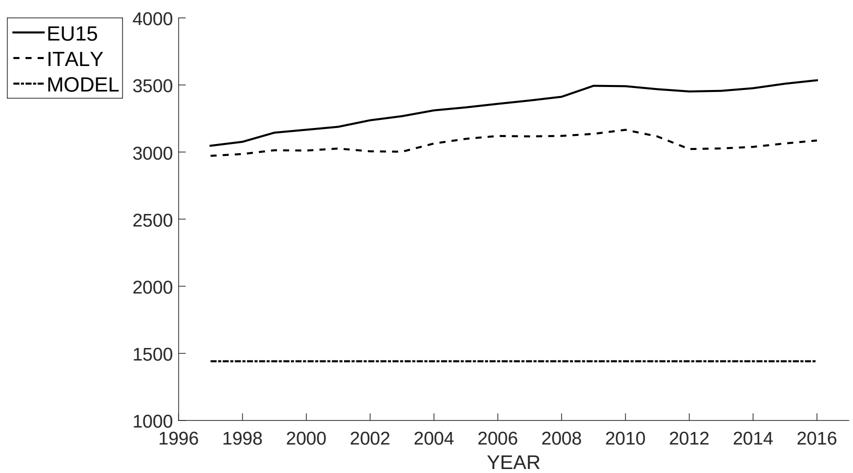
	Age Class							
	$25-29$	$30-34$	$35-39$	$40-44$	$45-49$	$50-54$	$55-59$	$60-64$
EU-15	74.13	79.52	81.13	81.29	79.71	74.3	60.33	32.04
ITALY	59.14	70.89	74.17	74.46	72.76	66.74	48.56	22.94
MODEL	97.88	99.72	99.64	99.61	99.49	99.2	98.66	87.65

Figure 24: *Employment rate by 5-year age classes (%). Values for EU-15 and Italy are elaborated from Eurostat data.*

This substantial positive bias between model outcome and empirical profile, averaged over the period $1998-2017$, mainly stems from the exclusion of nonparticipation, long term unemployment. Also the assumption of an automatic random hiring process contributes to feed this positive gap. The introduction of alternative matching process between unemployed workers and job vacancies over the life cycle are likely to deliver more acceptable results in this respect. This is exercise is left for future research.

C.2.4 Employed Wage

Similar to employment rate for the extensive margin of pension contributions, in the analysis of the interplay between labour market and pension systems, employed wage statistics are important inasmuch they shape the intensive margin of pension contributions.
The monthly mean of (gross) employed wages in the model (1141.05), depicted in figure 25, is less than half compared to what observed between 1997 and 2016 (3340.29 in EU-15 and 3059.5 in Italy). As expected from the consideration of only not-high skilled workers, the calibrated support for offered wage, ranging from $w_{min} = 500$ to $w_{max} = 2500$, results to be too low compared to the data.

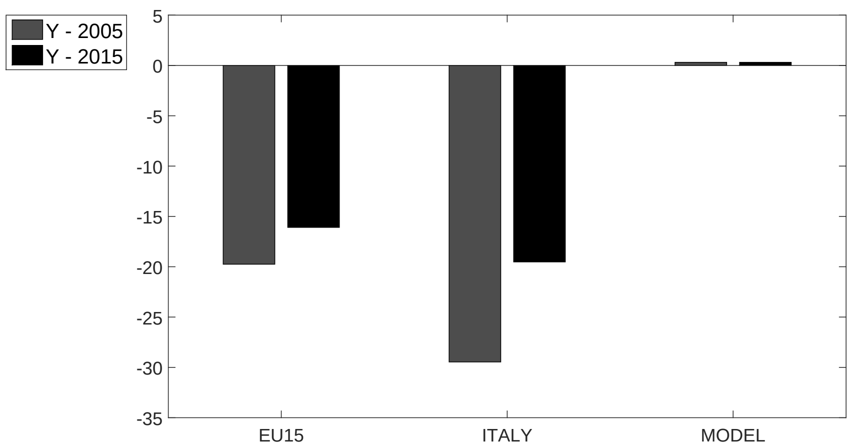


	EU-15	ITALY	MODEL
Avg Wage (monthly)	3340.29	3059.5	1497.17

Figure 25: *Average employed wage (monetary units, monthly) and wage gap between workers aged* $25-54$ *and* $55-64$ *(%). Values for EU-15 and Italy are elaborated from OECD data.*

In this case, the model not only excludes workers whose contract wage is bargained (e.g. executives, academics) but also workers whose posted wage exceeds a certain range. To reduce such a gap, both bounds of the wage distribution need to be increased, thus allowing for richer wage offers.
Another aspect under comparison, depicted in figure 26, is the gap between the average level of wage among workers aged $25-54$ and of those aged

55 − 64. The outcome produced by the model (0.31%) is not in line with values reported by the data (−18% in EU-15 and −12% in Italy) despite it is reducing between the years 2005 and 2015. Recalling figure 10, since the age profile of employed wage is not increasingly concave, then the gap is close to zero while empirical profiles are negative.



	EU-15	**Italy**	**Model**
Avg Wage Gap (%)	-0.18	-0.24	0.31

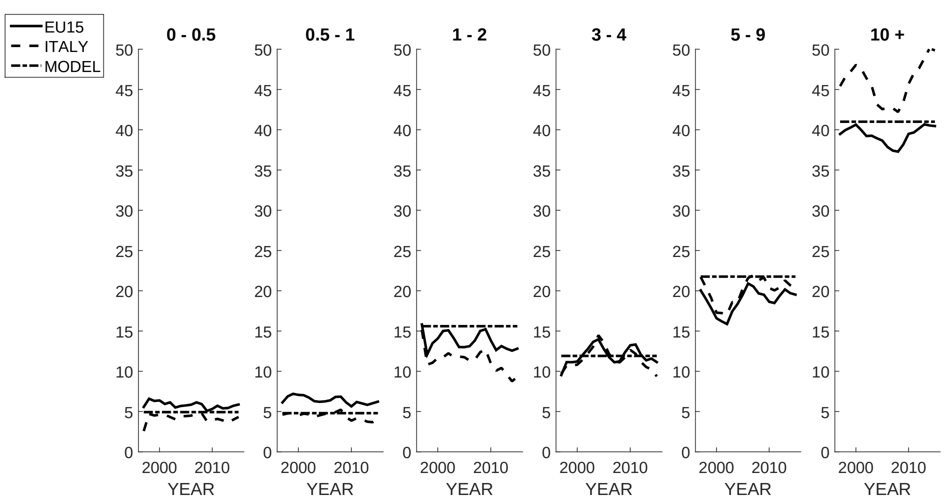
Figure 26: *Age Gap in Employed Wage (%). Values for EU-15 and Italy are elaborated from OECD data.*

In fact, also a factor for wage growth is absent in the model. Needless to say, this component would also contribute to increase the average level of employed wages in the economy.

Overall, increasing the support of offered wage and introducing a factor, or a mechanism, for wage growth over the life cycle would alleviate the gap between these model outcomes and corresponding empirical values. Fro example, apart from productivity or a seniority factor for wage growth, the presence of a labour market segment for younger workers characterised by a lower average wage would helps in this respect.

C.2.5 Tenured Employment Share

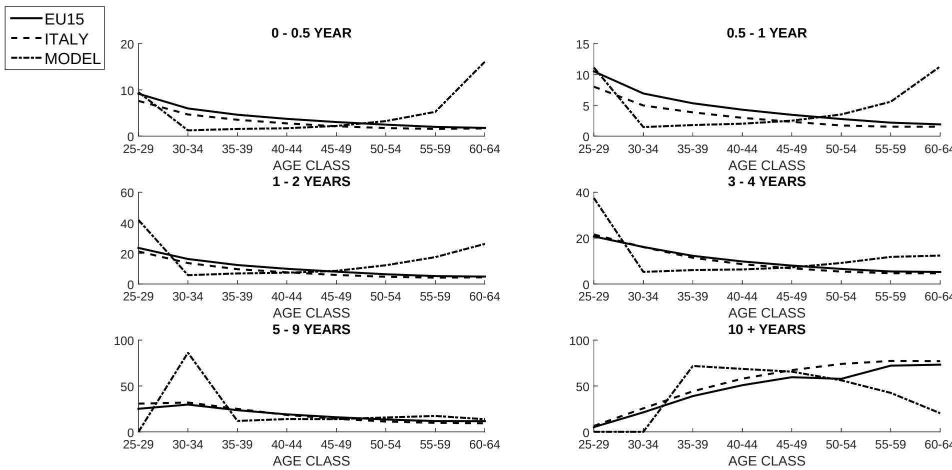
Regarding the employment tenure, for sake of empirical comparability, model outcomes are reported in terms of employment share and not rate. However, the higher the employment rate in the model (97.73%), the more the terms share and rate can be used interchangeably.
Figure 27 reports the distribution of the share of employment by tenure classes (in years) and compare it with the corresponding empirical counterpart for EU-15 and for Italy over the period $1997 - 2015$. In general, model outcomes are in line with reported by the data and closely mimic a tenure-increasing profile. For infrannual tenure classes $0 - H$ and $H - 1$, model outcomes (4.93% and 4.8%) are slightly lower compared to EU-15 (5.81% and 4.21%) but closer to those of Italy (4.21% and 4.44%). In the tenure class $1 - 2$ years the distance between model and data is substantially higher (15.6% vs 13.72% in EU-15 and 11.32% in Italy). Instead, model dynamics very well reproduces the share of employment in the tenure class $3 - 4$ (11.91% vs 11.97% in EU-15 and 11.53% in Italy).



Tenure Class	Tenure Class (years)					
	$0 - 0.5$	$0.5 - 1$	$1 - 2$	$3 - 4$	$5 - 9$	10+
EU-15	5.81	6.42	13.72	11.97	18.81	39.37
ITALY	4.21	4.44	11.32	11.53	19.99	45.92
MODEL	4.93	4.8	15.6	11.91	21.76	41

Figure 27: *Share employed workers (%) by tenure classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

While in the tenure class $5 - 9$ years, model outcome (21.76%) is slightly higher than what observed at empirical level (18.81% in EU-15 and 19.99% in Italy). Instead, in the last tenure class of 10+ years, model dynamics is more satisfactory if compared to EU-15 (41% vs 39.37%) and less when compared to Italy (41% vs 45.92). Overall, the assumption of uniformly distributed offered tenures whose maximal value depends on the age-distance to retirement of the employed worker as well as on tenure-decreasing firing rates. Possibly, improvements of model fitting can be obtained in this case through the introduction of workers' choices, not only in the form of reservation wages, but also adding the possibility of voluntary quits as form of on-the-job search.
Disaggregated by 5-years age classes in figure 28, model dynamics, still empirically valid, shows for which age group possible biases arise. It is possible to note that model dynamics delivers age-decreasing profiles for all tenure classes except for 10+ years, where it shows an increasingly concave profile. Moreover, the assumption of entry age $a_{min} = 25$ is responsible for the absence of employment in that tenure class for those age groups ($5 - 9$ and 10+ years for the age groups $25 - 29$ and $25 - 34$, respectively).

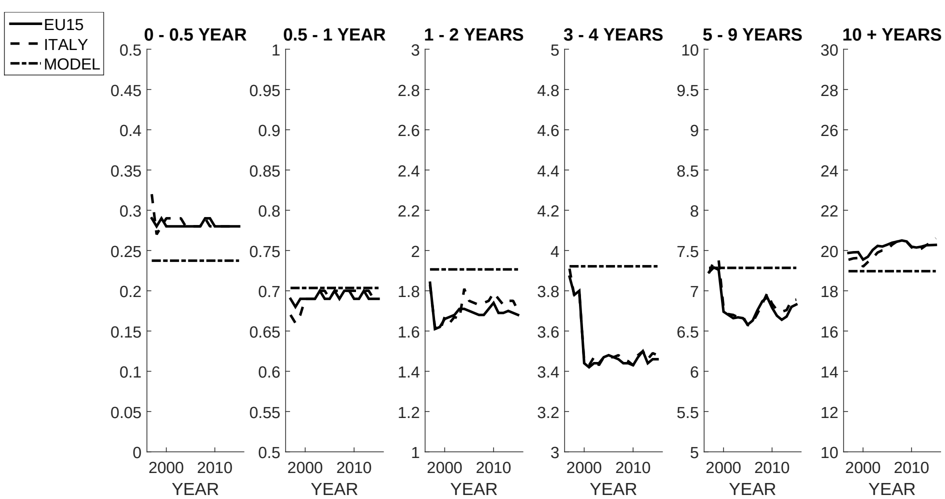


	Age Class							
	25 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64
Tenure Class: 0 − 0.5								
EU-15	9.17	5.99	4.63	3.74	3.05	2.49	2	1.78
ITALY	7.62	4.69	3.54	2.76	2.14	1.75	1.56	1.67
MODEL	9.5	1.25	1.56	1.71	2.21	3.26	5.26	16.08
Tenure Class: 0.5 − 1								
EU-15	10.5	6.92	5.33	4.29	3.46	2.78	2.19	1.91
ITALY	8.02	4.97	3.86	2.97	2.33	1.73	1.53	1.53
MODEL	11.13	1.47	1.8	2.02	2.51	3.52	5.58	11.3
Tenure Class: 1 − 2								
EU-15	23.59	16.35	12.4	9.93	8.05	6.37	5.16	4.85
ITALY	21.26	13.69	9.68	7.64	5.91	4.73	4.14	4.38
MODEL	41.89	5.75	6.9	7.39	8.58	12.26	17.56	26.2
Tenure Class: 3 − 4								
EU-15	20.72	16.14	12.27	9.83	8.03	6.57	5.47	5.23
ITALY	21.57	16.09	11.43	8.63	6.82	5.41	4.69	4.69
MODEL	37.47	5.27	6.07	6.34	7.23	9.17	11.81	12.39
Tenure Class: 5 − 9								
EU-15	25.14	29.72	23.58	19.05	15.91	13.45	11.72	11.64
ITALY	30.07	31.95	25.02	18.34	14.19	11.24	9.77	9.35
MODEL	0	86.26	11.87	13.93	13.84	15.63	17.32	13.72
Tenure Class: 10+								
EU-15	5.18	21.16	38.96	50.82	59.56	57.75	72.13	73.22
ITALY	6.44	25.63	44.18	57.94	67.25	74	77.27	77.06
MODEL	0	0	71.8	68.6	65.62	56.17	42.46	20.31

Figure 28: *Share of employed workers (%) by age and tenure classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

C.2.6 Average Employed Tenure

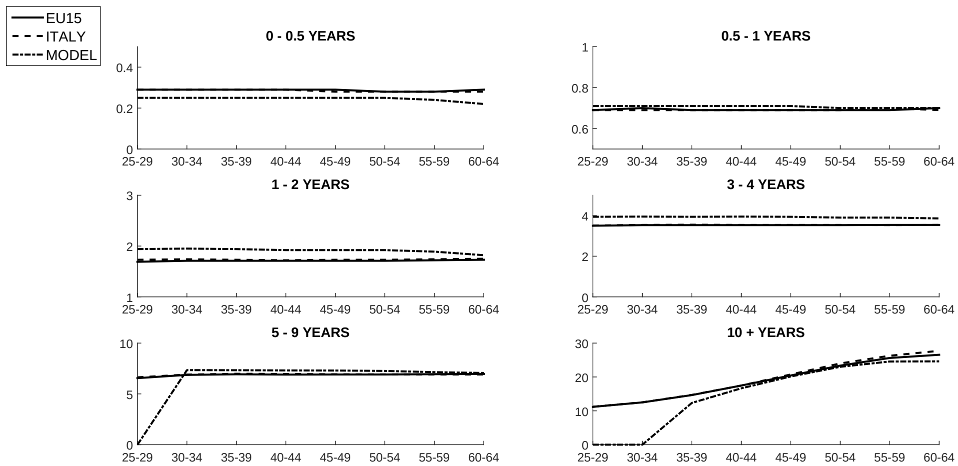
Along the comparison between model outcomes and empirical counterparts, besides the employment share, another perspective from which to consider tenure of employment relations is the distribution of average length by tenure classes. Similar to the distribution of employment share, the distribution of average employment tenure by tenure classes is firstly reported for the whole employed population and then disaggregated by 5-years age groups.
Figure 29 compares model outcomes with the data for EU-15 and for Italy, over the period 1997−2015, in terms of average employed tenure across tenure classes measured in years. Also in this case, the model well replicates the corresponding empirical profile. In the tenure class $0 - 0.5$ years, on average, employment relations last slightly less (0.24 years) than empirically observed (0.28 years in EU-15 and 0.29 years in Italy), with a negative gap between model outcome and empirical values of two weeks. In the other infrannual tenure class of $0.5 - 1$ year, the gap between model outcome (0.7 years) and the data (0.69 years both in EU-15 and in Italy) is negligible.



Avg Tenure	Tenure Class (years) $0-0.5$	$0.5-1$	$1-2$	$3-4$	$5-9$	10+
EU-15	0.28	0.69	1.69	3.51	6.81	20.13
Italy	0.29	0.69	1.72	3.52	6.85	20
Model	0.24	0.7	1.91	3.92	7.28	18.97

Figure 29: *Average employment tenure by tenure classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

Less satisfactory is the comparison within tenure classes of $1-2$, $3-4$ and $5-9$ years. In each of them, where model values are higher (1.91, 3.92 and 7.28 years, respectively) compared to what observed in EU-15 (1.69, 3.51 and 6.81, repsectively) and in Italy (1.72, 3.52 and 6.85 years, respectively). In the last tenure class of 10+ years, the negative gap between model outcome (18.97 years) and empirical counterparts (20.13 years in EU-15 and 20 years in Italy) implies that the model produces shorter long term relations.
Figure 30 decomposes by age the distribution of the average employed tenure by tenure classes. It is possible to note that, as in the data, the average duration of employment in the model does not show any age-specific pattern in any age classes but in the 10+ years. Note also that average tenure profiles for workers younger than 30 and 35 are null within the tenure classes of $5-9$ years and 10+ years, respectively. Within these tenure classes, the calibrated entry age in the labour market $a_{min} = 25$ implies that no workers aged $25-29$ can reach an employment duration of 5+ years.
Overall, the fitting of the model to the empirical profiles is more than satisfactory especially if one thinks that the dynamics of the labour market module in terms of employment duration is obtained by exogeneously (and arbitrarily) calibrating only two parameters generating labour market flows, i.e. the probability of job arrival and job separation. All the rest is due to the structure given to the model. Obviously, lowering the entry age into the labour market in accordance with the data, i.e. decreasing a_{min} to 15 years, can reduce the bias between model outcomes and empirical profiles especially to eliminate the null values of employment in the highest tenure classes for the lowest 5-years age groups. Since demography and offered contracts are strictly connected in the model economy, the introduction of a further age group $15-24$ alleviates such a drawback. This is one of the other alternative scenarios considered in appendix B.

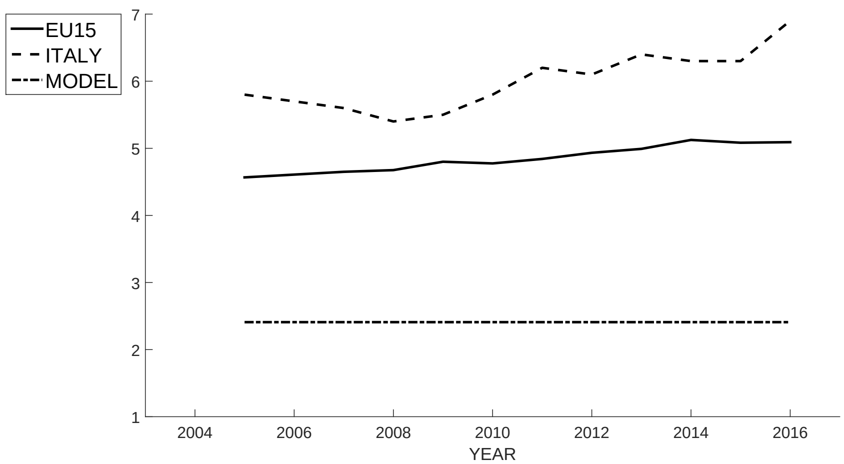


Avg Tenure (years)	Age Class (years) 25 − 29	30 − 34	35 − 39	40 − 44	45 − 49	50 − 54	55 − 59	60 − 64
Tenure Class: $0 - 0.5$								
EU-15	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.29
ITALY	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28
MODEL	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.22
Tenure Class: $0.5 - 1$								
EU-15	0.69	0.7	0.69	0.69	0.69	0.69	0.69	0.7
ITALY	0.69	0.69	0.69	0.69	0.69	0.69	0.7	0.69
MODEL	0.71	0.71	0.71	0.71	0.71	0.7	0.7	0.7
Tenure Class: $1 - 2$								
EU-15	1.69	1.71	1.71	1.71	1.71	1.71	1.72	1.73
ITALY	1.73	1.74	1.73	1.72	1.73	1.73	1.74	1.75
MODEL	1.94	1.95	1.94	1.92	1.92	1.92	1.89	1.82
Tenure Class: $3 - 4$								
EU-15	3.5	3.53	3.53	3.53	3.53	3.53	3.54	3.54
ITALY	3.51	3.54	3.55	3.54	3.54	3.54	3.53	3.54
MODEL	3.94	3.95	3.94	3.95	3.9	3.9	3.9	3.86
Tenure Class: $5 - 9$								
EU-15	6.55	6.87	6.93	6.9	6.91	6.91	6.94	6.96
ITALY	6.63	6.9	6.98	6.96	6.93	6.92	6.91	6.91
MODEL	0	7.34	7.33	7.31	7.3	7.26	7.14	7.06
Tenure Class: $10+$								
EU-15	11.17	12.49	14.65	17.47	20.44	23.35	25.61	26.55
ITALY	11.2	12.51	14.7	17.45	20.74	23.99	26.26	27.72
MODEL	0	0	12.33	16.65	20.14	23	24.56	24.61

Figure 30: *Average employed tenure by age and tenure classes (years). Values for EU-15 and Italy are elaborated from OECD data.*

C.2.7 In-Work Income Inequality and Poverty

The last statistics under comparison for the employed population concerns the level of inequality and poverty (post-social transfers) resulting from data on EU-15 and for Italy over the period $2004 - 2016$.
In term of in-work inequality, figure 31 shows that the outcome produced by the model (2.41) is much lower compared to the empirical counterparts, being nearly half of what observed (4.83 in EU-15 and 5.99 in Italy). In this case, the restricted wage dispersion as well as the lack of a mechanism that steeps the wage profile over the life cycle (figure 26) reduces the inequality associated to the employed population.

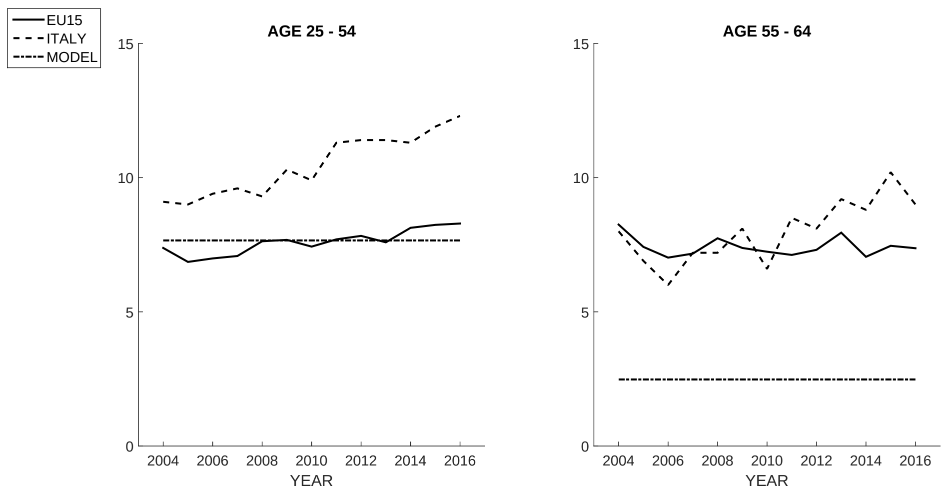


	EU-15	Italy	Model
Inequality (IQR)	4.83	5.99	2.41

Figure 31: *Inequality (income quintile ratio, IQR) among employed workers. Values for EU-15 and Italy are elaborated from Eurostat data.*

Indeed, the calibrated range of offered wages depicts only a part of the employed population, i.e. not-high-skilled dependent workers, excluding from the analysis those highly skilled workers for which contract wage is bargained in some cases like executives and academics.
In terms of in-work poverty, the situation is somehow similar since the lower wage dispersion affects also the number of working poors as confirmed by figure 32. Given a poverty line of 853.48 monetary units, the result produced by the model within the age group $25 - 54$ (7.66%) is line with the empirical

profile provided for EU-15 (7.6%) but it is downward biased if compared to the value for Italy (10.48%). A lower incidence of poverty characterises older employed workers aged $55-64$ because of the positive impact of social transfers provided by public welfare authoritie especially for this age group. Despite the decreasing age profile of in-work poverty also results from model dynamics, the outcome is lower compared to the data (2.48% in the model vs 7.42% in UE-15 and 7.98% in Italy).



	EU-15	**Italy**	**Model**
Poverty Rate 25-54	7.6	10.48	7.66
Poverty Rate 55-64	7.42	7.98	2.48

Figure 32: *Poverty (head-count ratio post-social trasnfer, %) among employed workers aged* $25-54$ *(left) and* $55-64$ *(right). Values for EU-15 and Italy are elaborated from Eurostat data.*

Reasons for such underestimation of the poverty rates are the same as described for in-work inequality. As such, model dynamics delivers a scenario that can be considered as a lower bound in terms of in-work inequality and poverty compared to what results from the empirical data. Also in this case, besides enlarging the range of offered wages and introducing a mechanism delivering steeper wage profiles over the life cycle, the introduction of a labour market segment for younger workers improves the empirical fitting of the model as shown by one of the alternative scenarios reported in appendix B.

C.2.8 Retirement Age

The last statistics under comparison regards the effective retirement age. Trivially, since the model excludes the possibility to retire earlier than the statutory retirement age a_{ret}, all workers retire when they just turn 65. As reported by 33 for the years $1970-2015$, the empirical profile for the effective retirement age is lower despite decreasing until the period $1995-2000$ and increasing thereafter thanks to the elimination of financial incentives Borsch-Supan (2000).

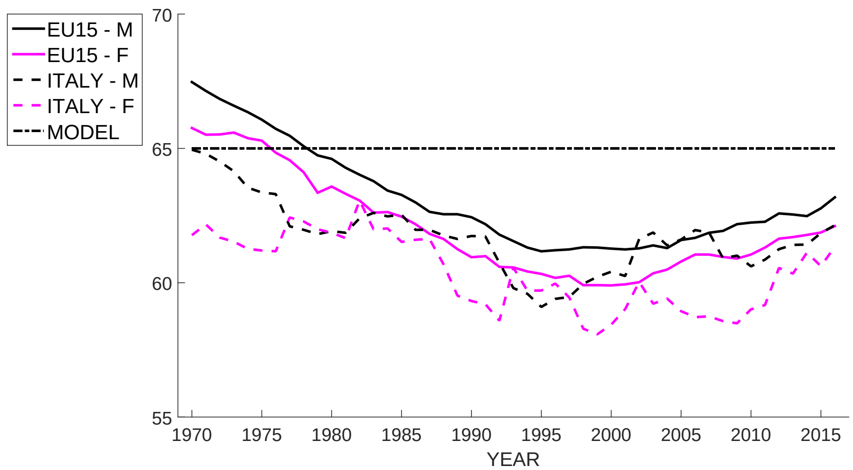


Figure 33: *Effective retirement age by gender in EU-15 and in Italy during the period* $1970-2016$ *(5-year average). Source: author's own elaboration on OECD data.*

Despite it is not the main focus of this work, the exclusion of early retirement limits the model ability to represents this important stylised fact since effective and statutory retirement ages coincide.

D Reservation Wage and Flexible Contracts

This section describes some behavioural extensions of the baseline model. In fact, the model described in this work is a random dynamical system since workers do not make any choices.
Coherently with the literature of frictional labour markets, labour supply is modelled in its extensive margin through a reservation strategy. This allows to equip workers with a device to choose whether or not to accept a given job offer. The same modelling strategy can be adopted to allow workers to search on the job, deciding whether to quit or not an ongoing employment relation once a new job offer is in place. In a similar fashion, since the main focus of this work is on pension systems, a reservation quantity can retrieved for the choice of early retirement. This appendix retrieves a closed formula for the extensive margin of labour supply. The other two are left to future research.
The seminal work of McCall (1970) retrieves the reservation wage as the optimal solution to a stopping problem, where employment is an absorbing state and search is random. In the third section of his paper, he extends the wage offer to a bidimensional object composed by wage and a fixed tenure. *Mutatis mutandis*, i.e. the tenure of the contract is age specific, the determination of a reservation wage when wage-tenure contracts are offered is the object of this sub-appendix. In particular, it is shown that the reservaton wage is tenure-specific and, so, age-specific since it depends on the age distance to retirement.
Let a_{min} and a_{ret} be the entry and retirement age in the model economy. Consider an unemployed worker aged $a \in [a_{min}, a_{ret} - 1]$ to whom a wage-tenure contract (w, t_a) is offered, with w and t_a representing the wage and tenure components. The two components are randomly drawn from their own pdf f_W, defined on the support $[w_{min}, w_{max}] \in \mathcal{R}_{++}$, and $f_{T,a}$. The tenure distribution is assumed to be a discrete uniform defined on an age-decreasing support $[1, a_{ret} - a - 1] \in \mathcal{N}^*$. All contracts are public information so that the unemployed worker is able to compute their mean quantities $\bar{w} = \int\limits_{w_{min}}^{w_{max}} w f_W(w) dw$ and $\bar{t}_a = \frac{a_{ret}-a}{2}$. He discounts future at a factor $\beta \in [0, 1]$[24]. The unemployed worker is risk neutral and enjoys a benefit

[24] Besides standard discounting, an alternative possibility is to introduce of hyperbolic discounting as a tool to analyse time inconsistency (Laibson, 1997). This idea has then

$b \in \mathcal{R}_{++}$ during unemployment spells. Assume that $b > w_{min}$, otherwise the unemployed worker accepts any job offer as trivially happens in the baseline version of the model. A contract offer arrives with probability ϕ. An ongoing employment relation ends with probability λ, which is assumed to be tenure-independent for sake of simplicity. Assume also that the tax rate is null or, equivalently, the received wage offer is net of taxes, e.g. net of pension contributions.
Thus, the tenure-specific value of unemployment $V^U(\bar{t}_a)$ is given by the sum between current payoff b and the discounted and uncertain future payoff. The latter quantity is expressed as a ϕ-weighted average between the average value of employment $V^E(\bar{w}, \bar{t}_{a+1})$ and the unemployment benefit b[25]:

$$V^U(\bar{t}_a) = b + \beta\Big[\phi V^E(\bar{w}, \bar{t}_{a+1}) + (1-\phi)b\Big] \tag{15}$$

and

$$\begin{aligned} V_a^E(w, t_a) &= w + \beta(1-\lambda)w + [\beta(1-\lambda)]^2 w + ... + [\beta(1-\lambda)]^{t_a - 1} w \\ &= w\Bigg\{\sum_{\tau=0}^{t_a-1}\big[\beta(1-\lambda)\big]^\tau\Bigg\} \end{aligned} \tag{16}$$

Let $\theta(t_a) = \Bigg\{\sum_{\tau=0}^{t_a-1}\big[\beta(1-\lambda)\big]^\tau\Bigg\}$ and indicate with $w_R(t_a)$ the reservation wage specific to tenure t_a, i.e. the level of wage equating $V^U(\bar{t}_a)$ and $V^E(w, t_a)$:

$$b + \beta\Big[\phi\bar{w}\theta(\bar{t}_a) + (1-\phi)b\Big] = w_R(t_a)\theta(t_a)$$

Rearranging, the reservation wage $w_R(t_a)$ can be expressed as:

$$w_R(t_a) = b\frac{1+\beta(1-\phi)}{\theta(t_a)} + \bar{w}\frac{\beta\phi\theta(\bar{t}_{a+1})}{\theta(t_a)} \tag{17}$$

been applied also to explain retirement choices, as in Findley and Caliendo (2015), and job search behaviour, as in DellaVigna and Paserman (2005) and Paserman (2008). Development of the model presented in this work along this direction is left to future research

[25]The author acknowledges that considering b as the future value of unemployment is an exemplifying assumption. If, as it should be, $V^U(t_{a+1})$ is considered, then there the curse of dimensionality occurs since the total number of states increases to more than eleven trillions at population level. A possible solution to reduce the dimensionality of the problem could be introducing short-term planning horizon for workers decisions as in Findley and Caliendo (2009) and Findley and Caliendo (2014). This is left to future research.

for $a = a_{min}, ..., a_{ret} - 3$. This shows that the level of reservation wage in such a context depends on both current unemployment benefit b, the first addendum, and on the average level of wage in the labour market, the second addendum.
When $a = a_{ret} - 2$, since $\theta(t_{a_{ret}-2}) = \theta(\bar{t}_{a_{ret}-2}) = \theta(1) = 0$, then $w_R(t_{a_{ret}-2})$ is no more tenure-specific and collapses to the standard case where only the wage level is considered. In this case, the reservation rule implies that $w_R(t_{a_{ret}-2}) = w_R(1) = b$. While for $a = a_{ret} - 1$, since there is no contract offer, a reservation quantity simply does not exsists.
So, given $w_R(t_a)$, the usual acceptance rule applies. If the wage w associated to an offered contract (w, t_a) is greater than $w_R(t_a)$, the unemployed worker accepts the offered contract. On the contrary, if $w \leq w_R(t_a)$, then he rejects the offer and prefers to keep on searching for better job opportunities.
From formula 17 above, it is important to note that the tenure-specific reservation wage $w_R(t_a)$ decreases when t_a increases, i.e. $\frac{\partial w_R(t_a)}{\partial t_a} < 0$, since $\frac{\partial w_R(t_a)}{\partial \theta(t_a)} < 0$ and $\frac{\partial \theta(t_a)}{t_a} > 0$. This explicitly shows that workers are more willing to accept contracts with higher tenures. This results extends the basic job search model of McCall (1970) to the case where job offers are characterised by a bidimensional contract. In section 3 of his paper, he put forward the idea of retrieving a reservation quantity in the case of a wage-tenure contract. After 50 years, equation 17 completes that section. And it does so by relating wage-tenure contracts, firstly formalised by Burdett and Coles (2003), whose length depends on the so called age-distance to retirement (Saint-Paul, 2009).

Life Expectancy Heterogeneity and Pension Fairness: an Italian North-South Divide

Fabrizio Culotta*

Abstract

This work documents the persistence in life expectancy heterogeneity by gender at level NUTS-1, macro areas, and NUTS-2, regions, for Italy during 1974-2016. Based on gender-by-geography deviations of life expectancy at age 65, it retrieves associated tax/subsidy rates triggered by the adoption of a single, common, factor for longevity in the pension formula.
Using data for life expectancy extracted from ISTAT mortality tables for age 65 from 1974 to 2016, empirical evidence at national level shows that female and male are subsidised and taxed by around 10% respectively. Differences by geography persist along the Italian territory. Since 1996 South and Islands have being taxed by 2%, Center and North-West macro-areas are being subsidised by around 1%, whereas North-East by 2%. At NUTS-2 level, directional transfers remain valid and more pronounced. A gender-differentiation of the longevity factor in the pension formula would reduce the intensity of the redistributive mechanism.

JEL Codes: D81, H55, J11, J14, J17, J18.

Keywords: Life Expectancy Heterogeneity, Tax/Subsidy Mechanism, Pension Systems, Italian Economy, Regional Divide.

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1 Introduction

From the second half of the XIX century, world population have been experiencing continuous increases in life expectancy, by around three months every year (Oeppen and Vaupel, 2002). This result was firstly obtained by improvements in infant mortality and, since the second half of the XX century, by improvements for people in old age. Italy was not immune from this trend[1]. Worldwide, to date, Italy is one of the most longeve country.
Since '90s, increases in life expectancy among old people have urged policy makers to reform the public pension systems. In fact, it is well-known that an ageing population threatens the financial sustainability of public pension systems. To counteract continuous improvements in longevity, increases in retirement age have been an unavoidable, but not innocuous, solution. Increasing retirement age without is not harmless in a context of systematic longevity heterogeneity, by some socioeconomic dimensions, among retirees. On this point, see Auerbach et al. (2017) for US and Whitehouse and Zaidi (2008) for OECD countries.
Recalling the definition of (average) actuarial fairness Holzmann and Palmer (2006), the internal rate of return that equals the discounted sum of pension contributions and payments over the life course must be (on average) the same across individuals. Accordingly, individuals known for their living shorter should be compensated from those who are known for their living longer. A pension system that does not account for such (systematic) heterogeneity violates (on average) actuarial fairness and triggers, instead, a redistribution of public resources that penalise those socioeconomic groups associated with shorter lives. Since improvements in longevity are neither randomly nor uniformly distributed across individuals, the resulting tax/subsidy mechanism redistribute resources among retirees. If, as often the case, life expectancy at retirement positively correlates with income, then such redistribution is regressive (Holzmann, 2017).
One of identifying properties of a Non-financial (unfunded) Defined-Contribution

[1] Caselli, Peracchi, Barbi and Lipsi (2003) estimates the gain (in years) in life expectancy by gender for different age groups between 1930-1950 and 1970-1995. For males aged 1-14, it decreased from 3.36 to 0.43, while for those aged 60-79 raised from 0.58 to 2.01 years. Similarly, for females aged 1-14 it decreased from 3.92 to 0.33 and increased for those aged 60-79 from 0.83 to 3.04 years.

(NDC[2]) is that pension benefits are constructed to reflect life expectancy at retirement Holzmann and Palmer (2006). This connection is expressed through a longevity factor which transforms the accumulated (and notionally capitalised) sum of pension contributions to a pension annuity. Since the longevity factor applied in practice is the (ex-ante) estimated for the whole population, systematic (ex-post) deviations trigger a stable redistribution of resources from those groups who systematically live shorter to those who live longer than commonly assumed. Hence, in an ageing population it becomes politically relevant to be aware on persistent redistributive patterns along some relevant socioeconomic dimensions. A typical case is from men to women (Holzmann and Palmer, 2006). As surveyed by Ayuso et al. (2017*b*), other dimensions over which one or more subgroups are being systematically subsidised or taxed are cohort, gender, education, geography, income, cohort, race, marital and health status. Empirical evidence confirms that heterogeneity in life expectancy, and thus the associated transfer mechanisms, is a phenomenon persisting for many industrialised countries over decades.

Since pension annuities are computed once for all, the ideal logic is to apply accurate estimates of life expectancy at time of retirement for each individual and keep updated such estimates. In this regard, Italy adopts an automatic revision of conversion factors every three (two, from 2019) years based on newly updated periodic mortality table. Belloni and Maccheroni (2013) shows that the more frequent the revision of coefficients, the lower the transfer across adjacent cohorts. While Ayuso et al. (2018) stresses the importance of using cohort, and not period, mortlaity tables in to update longevity factors.

Among possible interventions, Ayuso et al. (2017*a*) distinguishes among accumulation (post-contribution) phase, benefit determination (at retirement) and disbursement phase (after the first payment), and discuss pros and cons for each of them. These policy interventions are further examined by Holzmann et al. (2017). Interventions at retirement result desirable since changes in individual socioeconomic characteristics are less likely to occur after retirement.

The contribution of this work is threefold. Firstly, it extends and updates

[2]Despite the paper mainly focuses on the Italian NDC public pension system, much of the discussion is also valid for Defined-Benefit pension schemes. See Ayuso et al. (2018) for an analysis on Portuguese and Spanish public pension systems.

the geography of life expectancy in Italy for both males and females over 1974-2016. Secondly, it computes associated profiles of tax/subsidy rates between genders across different geographical areas (NUTS-1 and NUTS-2). Thirdly, it compares the intensity of the transfer mechanism with the case where pension formula is gender-differentiatiated.

Structure. This paper is organised as follows. Section 2 reviews the empirical literature on life expectancy heterogeneity in Italy. Section 3 provides empirical evidence. Section 4 computes associated tax/subsidy rates across Italian territories and by gender, proposes a policy of gender-differentiation and compares resulting intensities with the unconditional case. Section 5 concludes.

2 An Empirical Literature Review

The empirical literature on differentials in longevity across different socioeconomic groups can be dated back at least to Antonovsky (1967), who documents for U.S. the inequality in longevity by age, income class and profession[3]. A vast literature has then developed, favoured by an increasing availability of mortality data differentiated by some relevant socioeconomic groups. Recently for US, Chetty et al. (2016) reports that between 2001 and 2014 inequality in longevity across income groups has increased a great variation persists over geographical areas. Currie and Schwandt (2016) provides empirical evidence for inequality in longevity by age, etnies and gender for the period 1990-2010. Case and Deaton (2015) for the period $1999-2013$, which shows raises in mortality for Non-Black Non-Hispanic Americans aged $45-54$, especially among those with less education. See also Mackenbach et al. (2016) and Murtin et al. (2017) for recent cross-country analyses covering the period $1990-2010$ and years around 2011, respectively.
One of the early contributions for Italy is Natale and Bernassola (1973), which analyses mortality patterns by causes of death over 1790-1964. Caselli (1983) is the first work that, focusing on males aged 30-60 born in 1921, analyses differences across cohorts and along the Italian territory. It considers

[3] In the upfront of his paper, he recalls the official casualty list of the Titanic among females: 4 out of 143 (2.8%) from first class, 15 out of 93 (16.13%) from the second class and 81 out of 179 (45.25%) from the third class were drowned.

regions (NUTS-2) of Lombardy, Veneto, Latium and Calabria as representative for four Italian macro areas (NUTS-1), territorial disparities in longevity increase from age 30 to age 60. The study is then extended by Caselli and Reale (1999) to include both genders, the regions of Tuscany and Sicily and considers the period from 1951 to 1992. North-West gradually improves its position, North-East has recently improved, Centre Italy has improved in some regions and deteriorates in others, while the advantage of the South in the post-war years gradually diminishes. Overall, the geography of longevity is evolving over decades. The work of Caselli, Peracchi, Barbi and Lipsi (2003) is the first that relates heterogeneity in longevity with the actuarial fairness of the newly introduced NDC in 1996 in Italy. They estimate the difference between region-by-gender life expectancies and currently legislated values adopted when pension annuities are computed, concluding that conversions factors are very sensible to small variations in mortality probabilities. Given a survival gain of 1.2 years (1.5) for men (women) at age 60, they estimate that conversion factors for pension annuities need to be lowered by $2.5 - 3.2\%$ for ages 57-65 and by $3.6 - 4.3\%$ for ages 65+. Instead, by gender, they would need to be lowered by $0.5 - 1.81\%$ ($4.7 - 6.8\%$).
Focusing on the geography of mortality in Italy, Caselli, Cerbara, Heinsg and Lipsi (2003) describes describing the evolution of patterns for 94 provinces (level NUTS-3) by causes of death over early 70s and early 90s, thus presenting the first picture covering almost the totality of the national territory. Two contrasting, but expected, images emerge: a wealthier North and a poorer South that continually lags behind. Also Maccheroni (2006) concludes that dispersion is persistent, despite reducing, for Italian regions over the period 1960-2000 especially among females. Other works have focused on other relevant socioeconomic dimensions like education (Luy et al., 2011; Maccheroni, 2006, n.d.; Mackenbach et al., 2016; Mazzaferro et al., 2012), income inequality (De Vogli et al., 2005; Materia et al., 2005), income quintiles (Belloni et al., 2013) and occupations Belloni and Maccheroni (2013); Lallo and Raitano (2018); Mackenbach et al. (2016). Unfortunately, all these studies limit their findings at most up to the year 2000, with the only exception being Lallo and Raitano (2018); Maccheroni and Nocito (2017); Mackenbach et al. (2016) which use data beyond early 2000s but do not focus on geographical heterogeneity[4]. See table 1 for a comparative overview.

[4] Mackenbach et al. (2016) considers only the city of Turin, while Maccheroni and Nocito (2017) adopts the same dataset as in this work to backtest mortality forecasting

REFERENCE	SOCIOECONOMIC DIMENSION	DATASET	TIME PERIOD
Natale (1973)	Gender		1790 - 1964
Caselli (1983)	Cohort	Regional Mortality Tables	1882 - 1953
Caselli (1999)	Gender, Geography	Regional Mortality Tables	1952 - 1992
Caselli (2003a)	Cohort, Gender, Geography	ISTAT	1887 - 1997
Caselli (2003b)	Causes of Death, Cohort, Gender, Geography	Provincial Mortality Tables	1971-73, 1981-83, 1991-93
Conti (2003)	Cause of Death, Gender	ISTAT + ISS	1970, 1980, 1990, 1997
Materia (2005)	Gender, Income (Inequality)	ISTAT + MEF	1994
De Vogli (2005)	Income (Inequality)	ISTAT + SHIW + UN	1995, 1998, 2000, 2001, 2003
Caselli (2006)	Age (80-100), Gender, Sardinia	Provincial Mortality Tables	1975-77, 1996-97, 1998-2000
Maccheroni (2006)	Education, Gender, Geography	ISTAT	1960, 1970, 1980, 1990, 2000
Maccheroni (2009)	Education, Gender	ISTAT + CENSUS	2001
Luy (2011)	Education, Men, Occupation	ISTAT + CENSUS	1980 - 1994
Mazzaferro (2012)	Education, Income	ISTAT	1975 - 2000
Belloni (2013a)	Income (Quintiles)	INPS	1979 - 1990, 1991 - 2001
Belloni (2013b)	Cohort, Gender, Occupation	INPS + SHIW	1985 - 1997
Mackenbach (2016)	Education, Occupation	Turin Mortality Table	1990 - 2010
Maccheroni (2017)	Gender	ISTAT	1975 - 2014
Lallo (2018)	Occupation	EU-SILC + INPS	2005 - 2009

Table 1: *Empirical literature on life expectancy heterogeneity in Italy.* *Datasource*: *ISTAT* refers to mortality tables provided by the Italian Statistical Institute; *ISS* refers to the Istituto Superiore di Sanità; *MEF* to the Ministry of Economics and Finance; *SHIW* refers to the Survey of Household Income and Wealth from the Bank of Italy; *UN* stands for United Nations; *CENSUS* indicates Italian census data; *INPS* is the Italian social security institute; *EU-SILC* is the European Statistics on Income and Living Conditions.

Thus, no study documents geographical disparities in life expectancy after the financial crisis of 2007. Focusing on the period 1974-2016 and geography (NUTS-1 and NUTS-2), this work extends Caselli and Reale (1999), as well as Caselli, Peracchi, Barbi and Lipsi (2003), to a longer time span and a complete territorial coverage.
Like Caselli, Peracchi, Barbi and Lipsi (2003),Maccheroni (2006), Mazzaferro et al. (2012), Belloni and Maccheroni (2013), this work goes beyond the characterisation of the geography of mortality in Italy and analyses the link between longevity heterogeneity and distributional aspects of the Italian NDC pension system. But unlike previous works[5], Belloni and Maccheroni (2013) projects cohort mortality tables to analyse the actuarial characteristics of Italian pension system in a context of increasing longevity by adopting a deterministic forecast model. Mazzaferro et al. (2012) uses the CAPPDYn microsimulated model to compute the internal rate of return of the Italian NDC pension system. Maccheroni (2006) describes the evolution of mor-

models and Lallo and Raitano (2018) uses microdata for a time span of five years.

[5]In particular,

tality over a period of four decades, concluding that regional dispersion in longevity is persistent despite decreasing especially for males. Thus, none of them analyse the actuarial properties of the Italian pension system by exploiting the systematic heterogenity in life expectancy at retirement.
The adoption of a unique, homogeneous, longevity factor at population level triggers a redistributive mechanism from those retirees who will live longer than imputes in the computation of the pension annuity. Such heterogeneity can then translated into corresponding tax/subsidy profiles as done in Ayuso et al. (2017*b*) by gender and in Ayuso et al. (2017*a*) by cohorts. In this work, instead, focus is on geography and gender.It finally measures the intensity of the transfer mechanism. Finally, it compares the standard case with an intervention at retirement for which gender differentials in longevity are explicitly considered. As noted by Ayuso et al. (2017*a*) and Holzmann (2017), intervention at retirement, unlike those during accumulation and payment phases, is desirable if one considers that socioeconomic status are unlikely to change after withdrawn from labourforce.

3 Empirical Evidence

3.1 Data

This work uses data on life expectancy extracted from ISTAT database for mortality tables covering the period 1974-2016. This administrative dataset links death certificates of individuals in a given year to the area where resident. Implicitly, individuals are assumed to live in the area where the death certificate is registered. Time series are disaggregated by gender (Female, Male, Total) and by geography, i.e. NUTS-1 for macroareas and NUTS-2 for regions (see figure 1). This work focuses life expectancy at the age 65, proxy for retirement age, corresponding to the number of residual years that an individual aged 65 is expected to live[6].

[6]For a similar choice of age 65 as proxy for retirement, see also Whitehouse (2007), Whitehouse and Zaidi (2008), Mackenbach et al. (2016), Ayuso et al. (2017*b*), Ayuso et al. (2017*a*), Ayuso et al. (2018) and Holzmann et al. (2017). For lower (higher) ages, evidence and results provided in following sections can be considered as a lower (upper) bound for lower (higher) ages, since dispersion in life expectancy usually decreases with age. A refinement of the estimates of the tax/subsidy mechanism is to consider the effective retirement age and not the statutory limit. This exercise is left for further research.

NUTS-0	COUNTRY	NUTS-1	MACRO AREA	NUTS-2	REGION
IT	Italy	**ITC**	North-West	**ITC1**	Piedmont
				ITC2	Aosta Valley*
				ITC3	Liguria
				ITC4	Lombardy
		ITF	South	**ITF1**	Abruzzo
				ITF2	Molise*
				ITF3	Campania
				ITF4	Apulia
				ITF5	Basilicata
				ITF6	Calabria
		ITG	Islands	**ITG1**	Sicily
				ITG2	Sardinia
		ITH	North-East	**ITH1**	Province of Bolzano*
				ITH2	Province of Trento*
				ITH3	Veneto
				ITH4	Friuli-Venezia Giulia
				ITH5	Emilia-Romagna
		ITI	Center	**ITI1**	Tuscany
				ITI2	Umbria
				ITI3	March
				ITI4	Latium

Figure 1: *Classification of the Italian territory. Source: Eurostat (2018). Areas with asterisk are excluded for their negligible size of population.*

3.2 Evidence by Geography

Empirical evidence population level shows for Italy that life expectancy at age 65 increased during 1974-2016 from 15.14 to 20.72 (figure 2).

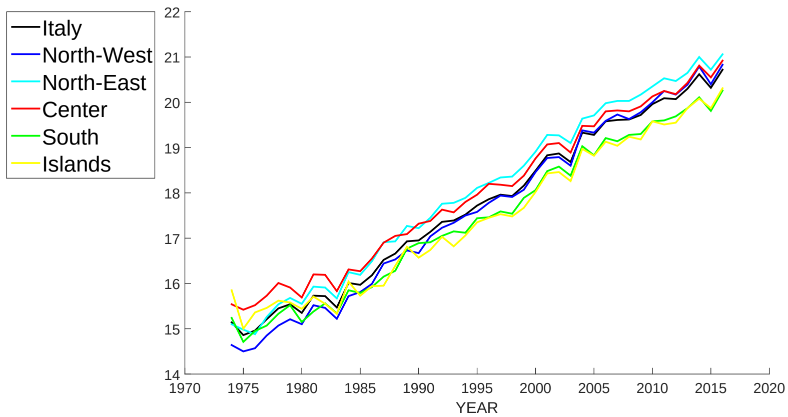

Figure 2: *Life Expectancy at age 65, from 1974 to 2016, for the total population in Italy across macro areas (NUTS-1). Source: ISTAT (2018).*

The division of Italy into macro areas depicts a clear divergence. Starting from the beginning of 90s, Mezzogiorno (South and Islands) has exhibited a lower profile compared to rest of Italy. In 1974, while Mezzogiorno and Center shared the same level of life expectancy (15.45 and 15.54 years, respectively), with North (North-East and North-West) showing the lowest (14.82 years), their position reversed from the second half of the '80s. In 2016, North Italy shares the same value with Center (20.92 years), while Mezzogiorno's longevity is half year lower (20.28 years). Moving to regions (figure 3), Campania in the South and Sicily in the Islands shows the lowest profile[7]. Whereas Trentino (North-East) and March (Center) show the highest value of longevity at 65.

[7]The result of Campania was also noted by Maccheroni (2006), which highlights the incidence of very high diabete-related mortality and cardiovascular diseases in the two regions. Also Caselli, Cerbara, Heinsg and Lipsi (2003) detects a pattern reversal, from North-East in 1971-73 to the South and Islands in 1991-93, of cyrrosis of the liver.

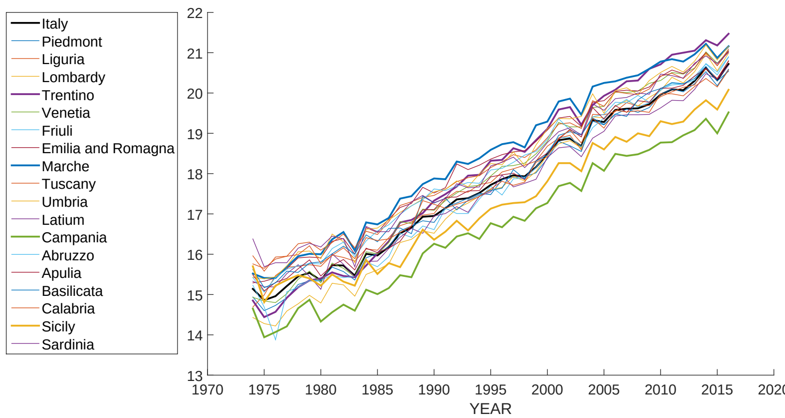

Figure 3: *Life Expectancy at age 65 for the total population in Italy, from 1974 to 2016, across regions (NUTS-2). Source: ISTAT (2018).*

It is interesting to note that in 1974 Campania and Trentino shared the same longevity (14.65 and 14.85 years), similar to Sicily and Marche (15.7 and 15.52). In 2016, after four decades, their values are 19.52 and 21.47 (2 years gap), 20.08 and 21.16 (one year gap) respectively.

3.3 Evidence by Gender

Persistent differences in life expectancy at age 65 characterise the Italian. South and Islands actually show the lowest profiles of longevity. This is especially true for Campania in the South, Sicily in the Islands. The rest of Italy, especially the regions of Trentino in North-East and March in the Center, enjoys an above-average longevity. Such geographical patterns also remains when longevity profiles are disaggregated by gender.

As figure 4 confirms, females live longer than men. A gap that increased to four years in 1974-1995, remained stable in 1996-2005 to reduce to three years since 2005 as it was four decades ago. Reasons for this narrowing in gender gap can be found in convergent, but unhealthy, lifestyle (stress, smoking, drinking) arose since women's emancipation (Caselli, Peracchi, Barbi and Lipsi, 2003; Conti et al., 2003; Liu et al., 2012; Maccheroni, 2006; Trovato and Lalu, 1996, 1998). Unlike the unisex picture provided at national level, disaggregation by gender depicted reveals that females of Mezzogiorno (South and Islands) have always maintained a negative gap with the rest of Italy since 1974. On the contrary, the male counterpart has started to diverge in 2005.

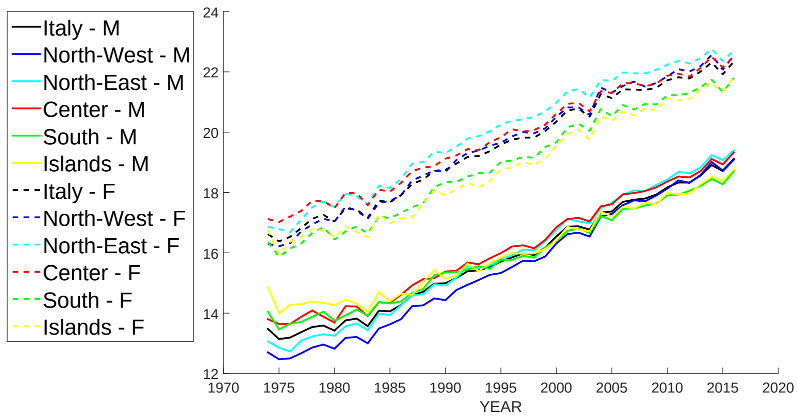

Figure 4: *Life Expectancy at age 65 for male and female population in Italy, from 1974 to 2016, across macro areas (NUTS-1). Source: ISTAT (2018).*

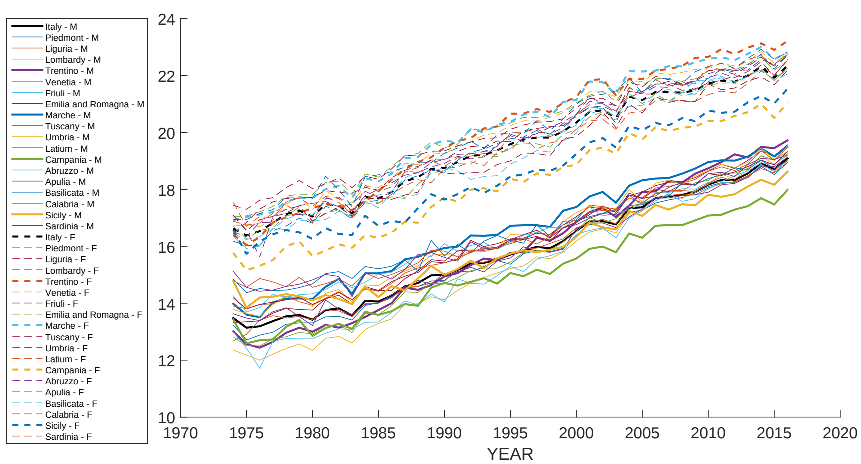

Figure 5: *Life Expectancy at age 65 for male and female population in Italy, from 1974 to 2016, across regions (NUTS-2). Source: ISTAT (2018).*

Figure 5 confirms that regions of Campania and Sicily are those contributing the most to the divergence between Mezzogiorno (South and Islands) and

the rest of Italy. Regions of March and Trentino, instead, share the highest values of longevity at age 65 both for male and female.
It is interesting to also report the evolution of dispersion, measured in standard deviation, of longevity across Italian territories. Dispersion across macro-areas (left panel) decreased from 0.4 in 1974 to a minimal of 0.25 in 1985 and increased to around 0.4 years in 2016. Dispersion across regions (right panel) shows a more stable pattern of around 6 months (0.5 years) during the four decades. In both cases, differences in life expectancy by geography are more pronounced for females than for males. Education plays a role in explaining such a difference between genders[8].

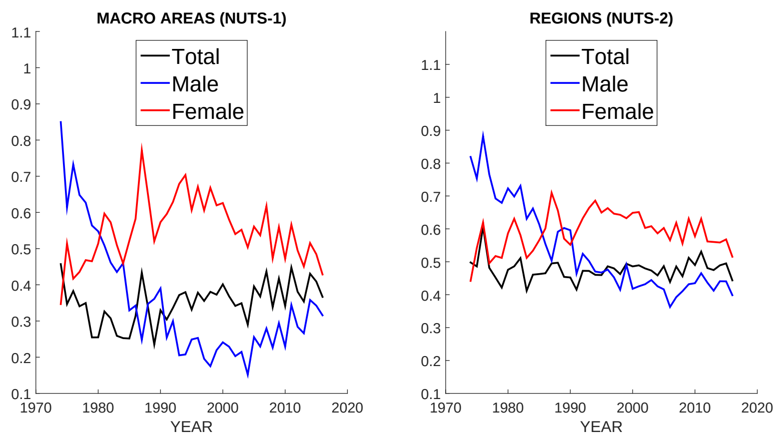

Figure 6: *Standard deviation of life expectancy In Italy at age 65 by gender and geography: macro areas (NUTS-1, left) and regions (NUTS-2, right). Source: Author's own elaboration on data from ISTAT (2018).*

Moreover, since 1996 dispersion is reducing for female but is increasing for males. Convergence is taking however place after 2005. At a first sight, a level of dispersion in life expectancy at age 65 of less than half year seem more than acceptable for a country like Italy. Next section will translate such persistent disalignments by gender and by geography into tax/subsidy rates. This will characterises the transfer mechanism operating from those areas where individuals live shorter (and so, they are taxed) to those where individuals live longer (and so, they are subsidised) than the common value imputed in the pension formula.

[8] I thank Prof. El Mekkaoui for having highlighted this aspect.

4 Results

4.1 The Tax/Subsidy Mechanism

This section provides results from computation of the implicit tax/subsidy rates specific for each gender-by-geography subgroups. Gender and territorial heterogeneity in longevity is now translated into rates at which the adoption of an homogeneous value for life expectancy reflects as tax/subsidy to individuals living shorter/longer than average. If deviations from the common value are systematic, then individuals receive a pension annuity which is lower/higher than the actuarially fair value.

The connection in the NDC pension formula between longevity heterogeneity at retirement and the tax/subsidy rate is expressed as in Ayuso et al. (2017*b*), Ayuso et al. (2017*a*), Holzmann et al. (2017) and Holzmann (2017). Let K be the value of pension capital at retirement for individuals i. Assume that a NDC pension annuity is simply computed dividing K by the value of life expectancy at population level LE. If (ex-post) deviations are systematic, i.e. $LE_i \neq LE$, then actuarial fairness would imply $P_i^F = \frac{K}{LE_i} \neq P = \frac{K}{LE}$. The tax/subsidy rate represents the percentage deviation of the standard pension P with the one that is actuarially fair for individual i, i.e. P_i^F. The rate τ_i can thus be expressed as:

$$\tau_i = \frac{P - P_i^F}{P_i^F} = \frac{\frac{K}{LE} - \frac{K}{LE_i}}{\frac{K}{LE_i}} = LE_i \left(\frac{1}{LE} - \frac{1}{LE_i} \right) = \frac{LE_i}{LE} - 1 \qquad (1)$$

The rate is negative/positive if individual i lives shorter/longer than imputed in P, i.e. if $LE_i < / > LE$. Pension capital is thus taxed/subsidised in the sense that the public pension system, implicitly through its pension formula, extracts/imputes extra resources from/to short/long-living retirees.

Following the logic expressed by equation 1, time profiles of tax/subsidy rates across Italian macro areas and regions are firstly reported for the whole population. Profiles are then disaggregated by gender. Lastly, a policy exercise of gender-differentiation is considered.

4.2 Tax/Subsidy Rates: geographical profiles

Let LE_t be the homogeneous value of life expectancy for individuals aged 65 at time t through which pension annuities are computed. Let $LE_{t,a}$ be the value of LE_t specific to the geographical area indexed by a and referring either to a macro-area (NUTS-1) or to a region (NUTS-2). Recalling equation 1, the rate of transfer at time t specific to area a, $\tau_{t,a}$, is defined as:

$$\tau_{t,a} = \frac{LE_{t,a}}{LE_t} - 1 \qquad (2)$$

where index t ranges from 1974 to 2016 and a represents an area of the Italian territory. The rate $\tau_{t,a}$ is positive if individuals in area a have a life expectancy at age 65 higher than that at country level LE_t. The rate is negative in the opposite scenario.

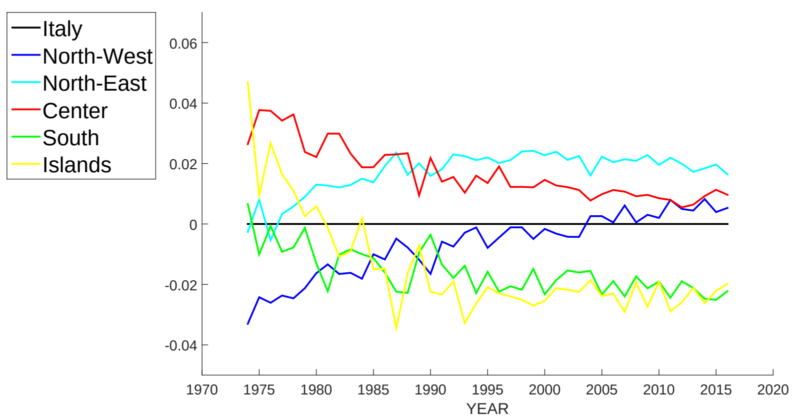

Figure 7: *Tax/Subsidy rate for Italian population aged 65 from 1974 to 2016 across macro areas (NUTS-1). Source: author's own elaboration on data from ISTAT (2018).*

As expected, figure 7 shows that the redistributive transfer within Italy persists over the last two decades. Individuals living in Mezzogiorno (South and Islands) are taxed by an average 2%. North-West and Center are both subsidised by 1% whereas North-East by 2%. Note that, after 2005, North-West reversed its position from tax-payer to subsidy-recipient. The North-South gap is increasing in the last decade. Figure 8 reports the same figures disaggregated by regions (NUTS-2), with rates ranging between 4% and -6%. Campania in the South is the most taxed region (around 6%), followed by Sicily in the Islands with around 4%). Among subsidised regions, Trentino in the North-East receives 4% while March in the Center declines from 4% to 2% after 2010.

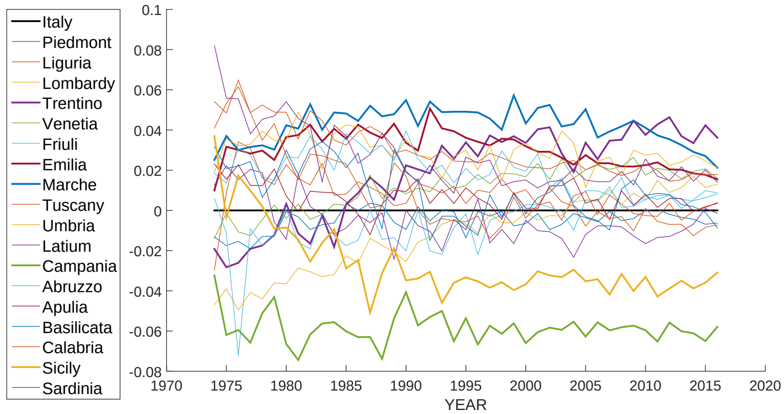

Figure 8: *Tax/Subsidy rate for Italian population aged 65 from 1974 to 2016 across regions (NUTS-2). Source: author's own elaboration on data from ISTAT (2018).*

4.3 Tax/Subsidy Rates: geography-by-gender profiles

Results are now disaggregated by gender. Recalling the tax/subsidy rate $ts_{t,a}$ defined in equation 2, the tax/subsidy rate specific to each geography-by-gender group at age 65, $\tau_{t,a,g}$, is computed as:

$$\tau_{t,a,g} = \frac{LE_{t,a,g}}{LE_t} - 1 \tag{3}$$

where $g = M$ stands for male and $g = F$ for female. As figure 9 shows, differences in life expectancy by gender translates into a stable transfer from males to females of around 10%[9]. For males it is possible to observe territorial convergence between 1996-2005 followed by divergence of Mezzogiorno (South and Islands) since 2006. It is interesting to observe the rapid improvement of North-East, whose tax profile moved from around 15% during 1975 to 10% after 1995 to be the lowest with around −6%. Female in Mezzogiorno do not show reversal trends since they have always had the lowest profile.

[9]Estimates of around 10% are also found for other (Southern) European countries like Portugal and Spain (Ayuso et al., 2017*a*,*b*, 2018). In 2014, while males are more taxed in Portugal than in Spain, females are more subsidised in Spain than in Portugal.

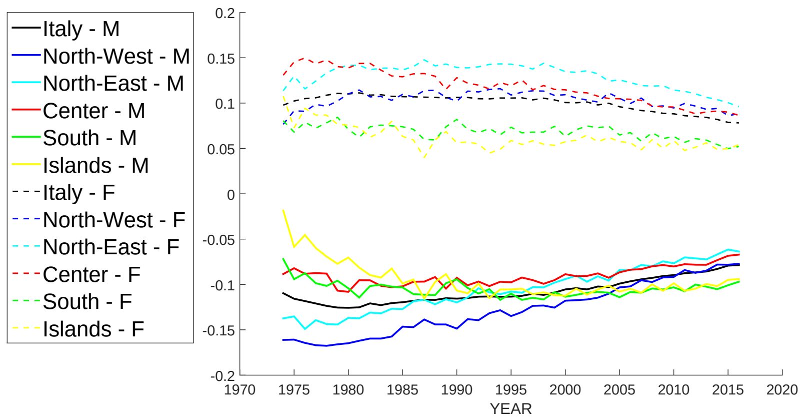

Figure 9: *Tax/Subsidy rate for Italian male and female population aged 65 from 1974 to 2016 across macro areas (NUTS-1). Source: author's own elaboration on data from ISTAT (2018).*

The geography of tax/subsidy profiles remain valid also if regions, and not macro areas, are considered. As depicted by figure 10, regions of Trentino (North-East), Marche (Center), Campania (South) and Sicily (Islands) lead results of the their macro-area.

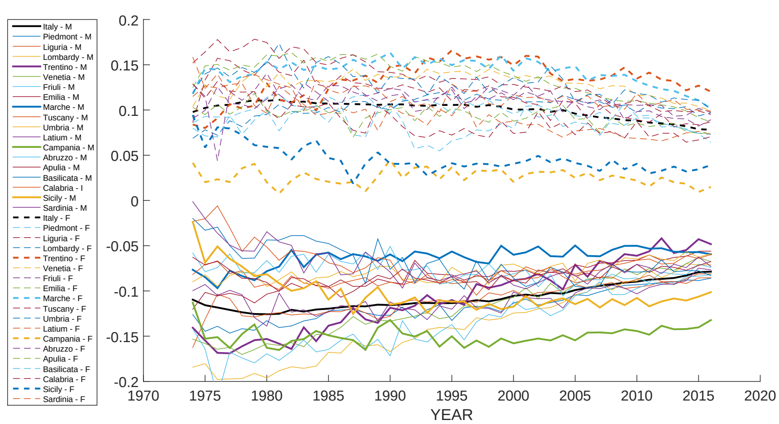

Figure 10: *Tax/Subsidy rate for Italian male and female population aged 65 from 1974 to 2016 across regions (NUTS-2). Source: author's own elaboration on data from ISTAT (2018).*

Lastly, figure 11 provides evidence for which dispersion of tax/subsidy rates is a longlasting feature. Morevoer, time profiles of standard deviations reveal that dispersion in life expectancy at age 65 within the Italian territory, for macro areas (NUTS-1, left) or regions (NUTS-2, right) is higher for females than for males but converging to 2%. In fact while dispersion among females is reducing, the one for male is increasing especially after the financial crisis of 2007-09 and the sovereign-debt crisis of 2010-2012.

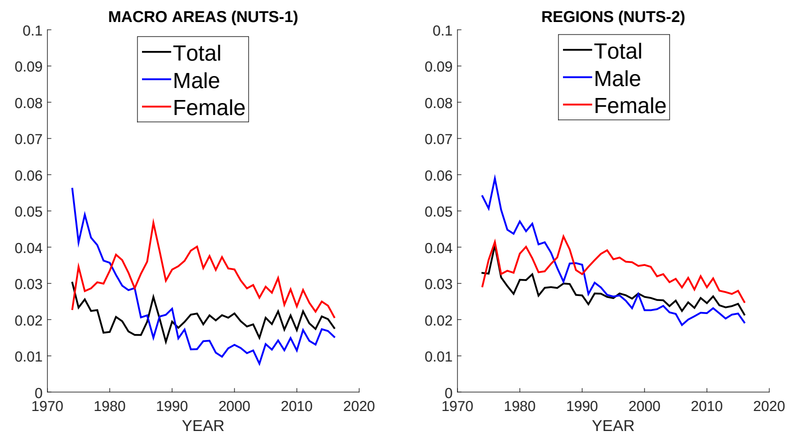

Figure 11: *Standard deviation of Tax/Subsidy rate for Italian total, male and female population aged 65 from 1974 to 2016 by geography: macro areas (NUTS-1, left) and regions (NUTS-2, right). Source: author's own elaboration on data from ISTAT (2018).*

4.4 Tax/Subsidy Rates: gender-differentiation

The case of gender-differentiation is now considered[10]. Accounting for differences in life expectancy by gender is expected to reduce, *sic et simpliciter*,

[10]The case of differentiation by geography is also considered. Overall, results show that intensity of the tax/subsidy mechanism is less reduced compared to the gender-differentiation case. Since gender differences are not accounted for, a stable gap persists also netting out geographical differences. Ask the author for supplementary material. Moreover, second-round effects resulting from possible manipulation of the residence just prior to retirement (especially for those living at the border between two different areas), let geographical differentiation a case which deserves further analysis. On the contrary, the gender dimension is less subject to manipulation in this respect.

the intensity of the tax/subsidy mechanism at retirement since controlling for gender-related differences silent the channel of heterogeneity due to gender-related factors[11].

Given $LE_{t,g}$ the average life expectancy at 65 specific for gender g, the tax/subsidy rate $\tilde{\tau}_{t,a,g}$ at time t in area a under the gender-differentiated scheme is defined as:

$$\tilde{\tau}_{t,a,g} = \frac{LE_{t,a,g}}{LE_{t,g}} - 1 \tag{4}$$

Looking at figure 12 two features emerge. Firstly, compared to the (unconditional) casein figure 9, the magnitude of tax/subsidy rates reduces to one third, from ±6% to ±2% over the period 1974-2016. Secondly, from 2005, South and Islands have been the only taxed macro areas.

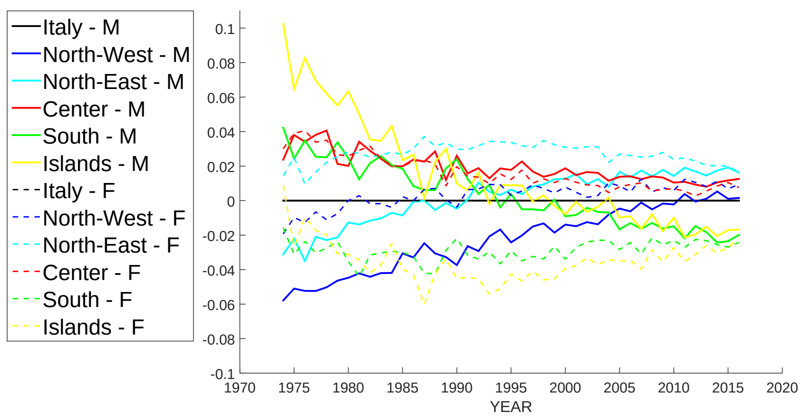

Figure 12: *Gender-differentiated tax/subsidy rate Italian population aged 65 from 1974 to 2016 by gender and by macro areas (NUTS-1). Source: author's own elaboration on data from ISTAT (2018).*

Disaggregation at regional level depicted by figure 13 confirms such general trends. Regions of Trentino and March are the most subsidised while

[11] As discussed by Ayuso et al. (2017*a*) and Holzmann et al. (2017), intervention at retirement is desirable since information about health status and past work career are known with less uncertainty. Operatively, it is easily implementable, perfectly verifiable and less subject to manipulation at individual level. On the other side, one should bear in mind that pension reforms implementing a gender-differentiation in the pension formula are likely to have an effect on labour careers of female individuals. What is expected, at least among the most sensible under *ceteris paribus* conditions, is that an increase in (effective) taxation will make their labour supply lasting longer.

Sicily and Campania are the most taxed. Unlike before, tax/subsidy profiles are now within a smaller band reducing from ±15% in the standard case (figure 10), to ±5%.

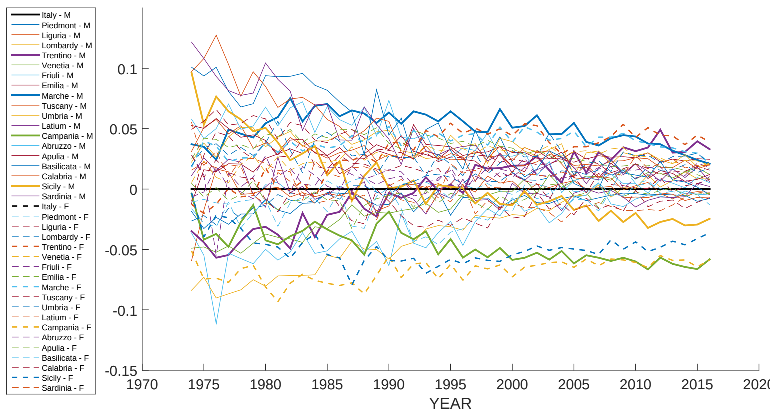

Figure 13: *Gender-differentiated tax/subsidy rate for Italian population aged 65 from 1974 to 2016 by regions (NUTS-2) and by gender. Source: author's own elaboration on data from ISTAT (2018).*

Finally, figure 14 reports that, if gender-specific value for life expectancy had been applied in the computation of pension annuities, dispersion of territorial profiles would have converged to a value of 2%. This is the same as in the unconditional case depicted in figure 11, meaning that considering gender-specific factors for longevity in the pension formula reduces only the magnitude of the transfer profiles (first-moment effect) but substantially does not impact on dispersion along geographical areas (NUTS-1, left, and NUTS-2, right).

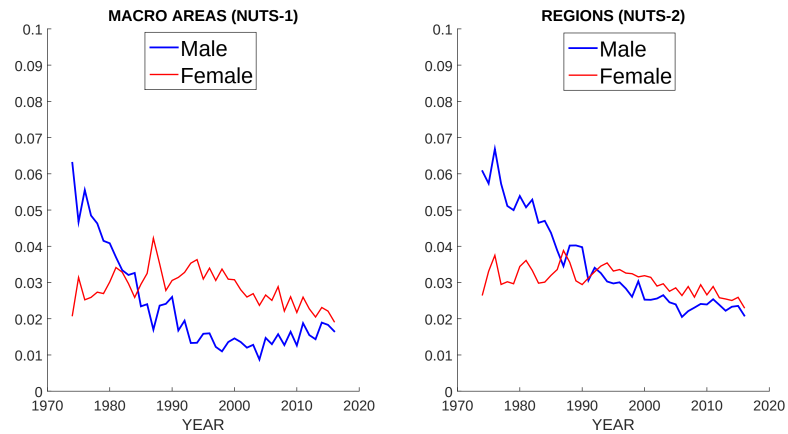

Figure 14: *Standard deviations of Tax/Subsidy rate for Italian population aged 65 from 1974 to 2016 by gender and by geography: macro areas (NUTS-1, left) and regions (NUTS-2, right). Source: author's own elaboration on data from ISTAT (2018).*

4.5 TATSI Analysis

Once profiles of unconditional tax/subsidy rate $\tau_{t,a,g}$ in equation 3 and gender-differentiated $\tilde{\tau}_{t,a,g}$ in equation 4 are retrieved, it is possible to measure intensity of the mechanism under each regime and then compare them. At this aim, the Total Absolute Tax/Subsidy Index (TATSI, Ayuso et al. (2017*a*); Holzmann (2017)) is computed. Focus is on the last two decades, i.e. on the period 1996-2016.

Defined as sum of absolute values over the socioeconomic dimension of analysis (i.e. geography), let $TATSI_{t,g}$ and $\widetilde{TATSI}_{t,g}$ be the index at time t for gender g for the standard and the gender-differentiated case respectively. Thus:

$$TATSI_{t,g} = \sum_a |\tau_{t,a,g}| \tag{5}$$

$$\widetilde{TATSI}_{t,g} = \sum_a |\tilde{\tau}_{t,a,g}| \tag{6}$$

where $|\cdot|$ refers the absolute value function.

As confirmed by figure 15, if public pension annuities had been computed under the gender-differentiated regime since the introduction of the NDC pension regime in Italy (i.e. the year 1996), the overall magnitude of the tax/subsidy mechanism across macro areas (NUTS-1, left) and regions (NUTS-2, right) would have been stabilised to around 0.1 and 0.5. On the contrary, the unconditional TATSI decreased from 0.6 in 1996 to around 0.5% in 2016 for macro areas and from 2 to 1.5 for regions[12].

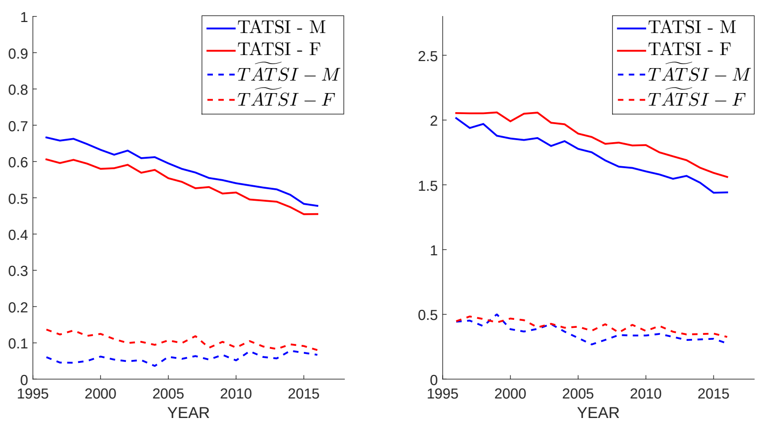

Figure 15: *TATSI profiles for unconditional and gender-differentiated tax/subsidy rates for Italian population aged 65 from 1996 to 2016 across for males and females. Aggregation by sub-macro-areas (left) and regions (right). Source: author's own elaboration on data from ISTAT (2018).*

5 Conclusions

This work provides empirical evidence for the evolution of life expectancy heterogeneity by gender and by geography, across macro areas (NUTS-1) and regions (NUTS-2), in Italy for the period $1974 - 2016$. The resulting analysis enriches the empirical literature on the relation between life expectancy heterogeneity and the actuarial fairness of pension systems. Profiles of tax/subsidy rates confirm that redistribution of pension resources still persists within the Italian territory. Divergence is observed between Mezzo-

[12]Note that the value of TATSI increases when one moves the analysis from macro areas to regions. This is does not necessarily reflect a higher intensity of the tax/subsidy mechanism among regions compared to acro areas. Indeed, since the higher the number entries the higher the corresponding intensity in terms of TATSI, a scaling factor is needed to correct such inflationary trend of the TATSI. Further improvements of this index are left for future research.

giorno (macro-areas of South and Islands) and the rest of Italy. Regions of Campania and Sicily drives the tax profile of South and Islands respectively, whereas Trentino and March do the opposite for macro areas of North-East and Center. Since Mezzogiorno (i.e. South and Islands) is the poorest area of Italy, the transfer mechanism inner to the standard earning-related pension system acts regressively. Concerning differences by gender, female (male) lives longer (shorter) than average which translates into persistent and sizeable profiles of tax/subsidy rates.

The standard design of the Italian public pension systems needs to be reformed towards a differentiation of its structural parameters, e.g. the longevity factor adopted to compute pension annuities. Doing so reduces the intensity of the tax/subsidy mechanism triggered at retirement, e.g. at age 65. Empirical results show that the intensity, measured in terms of TATSI, substantially lower both among males, females, across macro areas (NUTS-1) and regions (NUTS-2). Legislative constraints may impose the adoption of common life tables for computation of pension annuities, e.g. countries in the Europe Union (Ayuso et al., 2017*a*). This notwithstanding, a closer and updated monitoring of longevity heterogeneity along relevant socioeconomic dimensions is needed to make fully transparent redistributive performances of standard rules in public pension systems.

Further empirical research is also needed to quantify the impact of which factors, not only related to geography and gender, drive the most the dispersion of life expectancy along not only those socioeconomic dimensions.

References

Antonovsky, A. (1967), 'Social class, life expectancy and overall mortality', *The Milbank Memorial Fund Quarterly* **45**(2), 31–73.

Auerbach, A. J., Charles, K. K., Coile, C. C., Gale, W., Goldman, D., Lee, R., Lucas, C. M., Orszag, P. R., Sheiner, L. M., Tysinger, B. et al. (2017), 'How the growing gap in life expectancy may affect retirement benefits and reforms', *The Geneva Papers on Risk and Insurance-Issues and Practice* **42**(3), 475–499.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*a*), 'Addressing longevity heterogeneity in pension scheme design', *Journal of Finance and Economics* **6**(1), 1–21.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*b*), 'On the heterogeneity in longevity among socioeconomic groups: Scope, trends, and implications for earnings-related pension schemes', *Global Journal of Human-Social Science Research* **17**(1), 37–58.

Ayuso, M., Bravo, J. M., Holzmann, R. et al. (2018), 'Getting life expectancy estimates right for pension policy: Period versus cohort approach', *Institute for the Study of Labor (IZA)* (11512).

Belloni, M., Alessie, R., Kalwij, A. and Marinacci, C. (2013), 'Lifetime income and old age mortality risk in italy over two decades', *Demographic Research* **29**, 1261–1298.

Belloni, M. and Maccheroni, C. (2013), 'Actuarial fairness when longevity increases: An evaluation of the italian pension system', *The Geneva Papers on Risk and Insurance-Issues and Practice* **38**(4), 638–674.

Case, A. and Deaton, A. (2015), 'Rising morbidity and mortality in midlife among white non-hispanic americans in the 21st century.', *Proceedings of the National Academy of Sciences of the United States of America* **112**(49), 15078–15083.

Caselli, G. (1983), 'Il contributo dell'analisi per generazioni allo studio della geografia della mortalita", *Genus* pp. 37–60.

Caselli, G., Cerbara, L., Heinsg, F. and Lipsi, R. M. (2003), 'What impact do contextual variables have on the changing geography of mortality in italy?', *European Journal of Population/Revue européenne de Démographie* **19**(4), 339–373.

Caselli, G., Peracchi, F., Barbi, E. and Lipsi, R. M. (2003), 'Differential mortality and the design of the italian system of public pensions', *Labour* **17**, 45–78.

Caselli, G. and Reale, A. (1999), 'Does cohort analysis contribute to the study of the geography of mortality?', *Genus* pp. 27–59.

Chetty, R., Stepner, M., Abraham, S., Lin, S., Scuderi, B., Turner, N., Bergeron, A. and Cutler, D. (2016), 'The association between income and life expectancy in the united states, 2001-2014', *Jama* **315**(16), 1750–1766.

Conti, S., Farchi, G., Masocco, M., Minelli, G., Toccaceli, V. and Vichi, M. (2003), 'Gender differentials in life expectancy in italy', *European journal of epidemiology* **18**(2), 107–112.

Currie, J. and Schwandt, H. (2016), 'Mortality inequality: the good news from a county-level approach', *Journal of Economic Perspectives* **30**(2), 29–52.

De Vogli, R., Mistry, R., Gnesotto, R. and Cornia, G. A. (2005), 'Has the relation between income inequality and life expectancy disappeared? evidence from italy and top industrialised countries', *Journal of Epidemiology & Community Health* **59**(2), 158–162.

Holzmann, R. (2017), 'The abcs of nonfinancial defined contribution (ndc) schemes', *International Social Security Review* **70**(3), 53–77.

Holzmann, R., Alonso-Garcia, J., Labit-Hardy, H. and Villegas, A. M. (2017), Ndc schemes and heterogeneity in longevity: Proposals for redesign, Technical Report 11193.

Holzmann, R. and Palmer, E. (2006), *Pension reform: issues and prospects for non-financial defined contribution (NDC) schemes*, The World Bank.

Lallo, C. and Raitano, M. (2018), 'Life expectancy inequalities in the elderly by socioeconomic status: evidence from italy', *Population Health Metrics* **16**(1), 7.

Liu, Y., Arai, A., Kanda, K., Lee, R. B., Glasser, J. and Tamashiro, H. (2012), 'Gender gaps in life expectancy: generalized trends and negative associations with development indices in oecd countries', *The European Journal of Public Health* **23**(4), 563–568.

Luy, M., Di Giulio, P. and Caselli, G. (2011), 'Differences in life expectancy by education and occupation in italy, 1980–94: Indirect estimates from maternal and paternal orphanhood', *Population studies* **65**(2), 137–155.

Maccheroni, C. (2006), 'La mortalità differenziale: un fattore demografico di cui la riforma del sistema previdenziale non tiene conto adeguatamente', *Quaderni Europei sul Nuovo Welfare* (5), 76–84.

Maccheroni, C. (n.d.), 'Una stima della speranza di vita per grado d'istruzione in italia all'inizio degli anni 2000', *Polis* .

Maccheroni, C. and Nocito, S. (2017), 'Backtesting the lee–carter and the cairns–blake–dowd stochastic mortality models on italian death rates', *Risks* **5**(3), 34.

Mackenbach, J. P., Kulhanova, I., Artnik, B., Bopp, M., Borrell, C., Clemens, T., Costa, G., Dibben, C., Kalediene, R., Lundberg, O. et al. (2016), 'Changes in mortality inequalities over two decades: register based study of european countries', *BMJ* **353**.

Materia, E., Cacciani, L., Bugarini, G., Cesaroni, G., Davoli, M., Mirale, M. P., Vergine, L., Baglio, G., Simeone, G. and Perucci, C. A. (2005), 'Income inequality and mortality in italy', *The European Journal of Public Health* **15**(4), 411–417.

Mazzaferro, C., Morciano, M. and Savegnago, M. (2012), 'Differential mortality and redistribution in the italian notional defined contribution system', *Journal of Pension Economics and Finance* **11**(4), 500–530.

Murtin, F., Mackenbach, J., Jasilionis, D. and d'Ercole, M. M. (2017), 'Inequalities in longevity by education in oecd countries', *OECD Statistics Working Papers* (2).

Natale, M. and Bernassola, A. (1973), 'La mortalità per causa nelle regioni italiane: tavole per contemporanei 1965-66 e per generazioni 1790-1964', *Facoltà di Scienze statistiche demografiche ed attuariali, Università di Roma* **25**.

Oeppen, J. and Vaupel, J. W. (2002), 'Broken limits to life expectancy.(policy forum: Demography)', *Science* **296**(5570), 1029–1031.

Trovato, F. and Lalu, N. (1996), 'Narrowing sex differentials in life expectancy in the industrialized world: early 1970's to early 1990's', *Social Biology* **43**(1-2), 20–37.

Trovato, F. and Lalu, N. (1998), 'Contribution of cause-specific mortality to changing sex differences in life expectancy: Seven nations case study', *Social biology* **45**(1-2), 1–20.

Whitehouse, E. (2007), 'Life-expectancy risk and pensions: who bears the burden?', *OECD Social, Employment, and Migration Working Papers* (60).

Whitehouse, E. R. and Zaidi, A. (2008), 'Socio-economic differences in mortality', *OECD Social, Employment, and Migration Working Papers* (71).

Education and Life Expectancy at Retirement in Italy: an Implicit Tax/Subsidy Mechanism

Fabrizio Culotta*

Abstract

This work documents the persistence in life expectancy heterogeneity by gender and education in Italy for the years $2012 - 2014$. Based on gender-by-education deviations of life expectancy at retirement, it retrieves associated tax/subsidy rates triggered by the adoption of a homogeneous factor for longevity in the pension formula.
Using recently available ISTAT data for ages $57 - 65$, empirical evidence shows that male and female are respectively taxed and subsidised across all levels of education. Among men, those with at most primary education are taxed by around 12% whereas those with tertiary education by around 1%. On the contrary, women with the lowest and highest level of education are subsidised by around 6% and 12% respectively. Associated age profiles of tax/subsidy rates reveal that, for each level of education, the profile for men is age-decreasing whereas the one for female increases. A gender-differentiation of the longevity factor in the pension formula not only would massively reduce the intensity of the redistributive mechanism across ages, but it would also flatten its age profile for both genders.

JEL Codes: D81, H55, J11, J14, J17, J18.

Keywords: Life Expectancy Heterogeneity, Tax/Subsidy Mechanism, Pension Systems, Italian Economy, Education.

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1 Introduction

Life expectancy at a certain age is the reference measure for the remaining lifetime of an individual. As such, it is fundamental when computing life annuities as pension benefits, forecasting liabilities and timing reforms of the pension system. Apply correct estimates for life expectancy is beneficial for individuals because it can help to not distort their labour and saving choices, for example saving less and dissaving faster in case of shorter lives. It can be beneficial for the public pensions, since it provides more accurate estimates of the degree of financial solvency, adequacy and progressivity of the system. For instance, when pension benefits are computed based on the assumption of longevity homogeneity, a longer (ex-post realised) life expectancy represents for the retired individual a gain with respect to what would have been actuarially fair.

Majority of public pension systems, especially of defined-contribution type, adopts a common value for life expectancy to convert accumulated pension assets of the newly retired worker into a corresponding life annuity. This common value represents the value of life expectancy that individuals at retirement on average have. For example, in a (unfunded) defined-contribution pension scheme, this procedure ensures that the system satisfies the property of actuarial fairness on average (Belloni and Maccheroni, 2013; Holzmann and Palmer, 2006). Under this rule, if population is characterised by a systematic longevity heterogeneity across particular socioeconomic groups, once a common value is applied in the pension formula, long-living retirees will implicitly benefit from receiving an annuity for a longer period. The opposite happens for members of those groups who, at retirement, systematically live shorter than imputed by the pension rule[1].

Changes in life expectancy is an ongoing process since at least 150 years, linearly increasing by three months per year (Oeppen and Vaupel, 2002). During the period 1975-2015, figure 1 shows, for a pool of 12 European countries, the evolution of life expectancy by gender at retirement (age 65). For men (women), average life expectancy increased by five years, from 13 (16) in 1975 to 18 (21) years in 2015. Cross-country standard deviation decreased from 0.98 (0.92) in 1975 to 0.48 (0.82) years in 2015. While the gender gap, female minus male, slowly reduces from 3.4 in 1975 to 3.2 years in 2015.

[1]This is a case of the well-known risk-pooling problem in the insurance market: if the same price is paid for an annuity offered to different people, those with high risk and low risk are unequally treated.

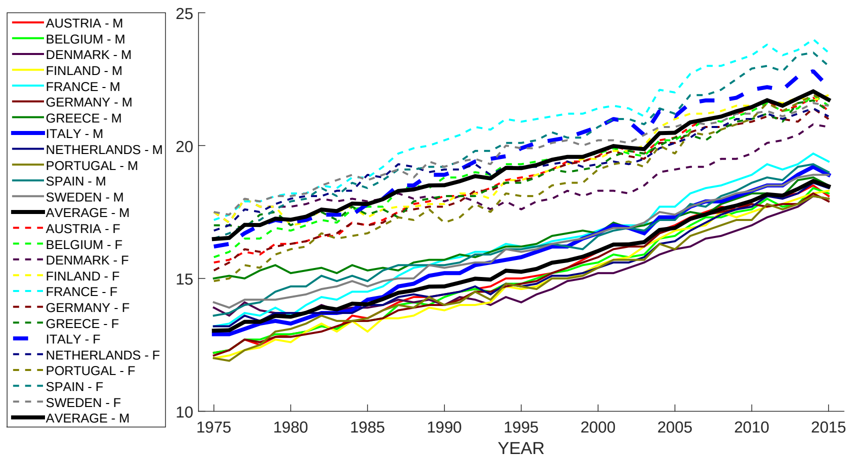

Figure 1: *Life expectancy at age 65 during 1975-2015. Female (F) and Male (M) population. Source: OECD (2018).*

Unfortunately, this stable gender gap of about three years triggers a redistributive tax/subsidy[2] mechanism at retirement, since the public pension system adopts a common factor for longevity to computes pension annuities[3]. Even though continuous, increases in life expectancy are neither randomly nor uniformly distributed across the population since they tend to concentrate among members of particular socioeconomic groups, e.g female.

[2]The term tax/subsidy refers to the amount by which contribution needs to be increased/decreased in order to be coherent with the benefit actually received and implied by a higher/lower common value of life expectancy considered in the pension formula (Holzmann et al., 2017). Equivalently, it can be seen as a measure of lost/gained pension income since it expresses the portion of accumulated pension assets that could have been elsewhere consumed or saved.

[3]An example is provided. Suppose that, within a country, males live until age 75 and women until age 85. Retirement age is 65 and imputed life expectancy at retirement is the average $\frac{10+20}{2} = 15$. Accordingly, men live 5 years less while women live 5 years more than $65 + 15 = 80$, i.e. the average life expectancy at retirement at population level. With these values, male is taxed by $\frac{(75-65)-(80-65)}{80-65} \times 100 = -33\%$ while female is subsidised by $\frac{(85-65)-(80-65)}{80-65} \times 100 = 33\%$ when their pension annuities are computed. Note that, by construction of the example, negative and positive values perfectly compensate. If they were not, then the rest would be shouldered directly by the public pension provider. For example, assuming that men and women were living 1 year more, i.e. 76 and 86, would result in a tax rate for men of -0.26% and a subsidy rate for women of 0.4%. In this case, the uncompensated subsidy rate of 0.14% is at the expenses of the pension provider.

Gender is the first dimension along which heterogeneity in longevity has been analysed. But it is not the only one. As surveyed by Ayuso et al. (2017*b*), works studying longevity heterogeneity have considered other socioeconomic factors as education, profession, income, geography, ethnicity: longevity heterogeneity is sizeable and not likely to decrease in the near future. All these dimensions act synergically and the specific contribution is difficult to disentangle. Indeed, the main difficulty relates to availability of administrative data which are usually not directly linked to other socioeconomic dimension apart from age, cohort, gender and geography. Recently (since June 2017), instead, data on longevity inequality by education are available for the first time also for Italy.
Based on ISTAT and OECD mortality tables by education, the contribution of this work is twofold. Firstly, it estimates profiles of tax/subsidy rates associated to longevity heterogeneity by education in Italy during the period 1975-2015. Secondly, it proposes a gender-differentiated intervention at retirement by applying gender-specific factors for longevity when pension annuities are computed.

Structure. This paper is structured as follows. Section 2 reviews the empirical literature on the relation between education and life expectancy heterogeneity with a special focus on Italy. Section 3 describes the data. Section 4 provides results in terms of tax/subsidy rates at age 65, proposes a gender-differentiated policy and compares its intensity with the unconditional case also in the age range $57 - 65$. Section 5 concludes. Appendix A speculates on the negative influence of skills mismatch.

2 Literature Review

Since Kitagawa and Hauser (1973), many studies have analysed the impact of education on life expectancy, reporting persistent and increasing time trends. Education represents a proxy for socioeconomic status, being a relevant variable for prospected careers and for the level of wealth. Education exerts a positive effect on life expectancy both at individual level, since more educated people are more prone to healthier lifestyles, and at aggregate level, since it propagates towards the less educated part of society[4].

[4]Exploiting compulsory school reforms in 18 European countries, Gathmann et al. (2015) finds that mortality gains from education for males are small both in the short

The empirical literature on educational inequality in longevity has provided strong evidence both over time and across countries, especially for the US, of persistent differential trends. Preston and Elo (1995) reports for US that educational inequalities in mortality widened for males while reduced for females over the period 1960-1980. The same conclusion holds even after controlling for income, marital status and geography of residence Elo and Preston (1996). A widening gap in life expectancy by education is also documented during the period 1981-2000 by Meara et al. (2008) and during 1999-2007 by Miech et al. (2011). Lastly, Case and Deaton (2015) provides evidence of widening dispersion by education and ethnicity during 1999-2013, covering for the first time the post-crisis period[5].
Other advanced countries experienced the same raise in mortality differentials by education. For example Murphy et al. (2006) reports that Russian men aged 20 with tertiary education, compared to those with elementary education, increased their longevity gap from 3 years in 1980 to 11 in 2001. In a cross-country perspective, Mackenbach et al. (1999) compares differences in mortality across a pool of seven countries (among which, Italy) during the 80s and the '90s to conclude that inequality in mortality by education is higher for men than for women for all causes of death. For the same period, a widening gap in life expectancy by education is also found for Scandinavian countries but not for New Zealand Fawcett et al. (2005). Van Raalte et al. (2011) for the years around 2000 for a pool of ten European countries, reports that less educated people not only have a shorter life expectancy but also higher dispersion by age than more educated individuals. Mackenbach et al. (2016) extends Mackenbach et al. (1999) to more than ten European countries, but with Italy represented by the city of Turin, during a two-decades time window, i.e. 1990-2010, covering also the post-2007 period. Lastly, Murtin et al. (2017) assesses for the year 2011 studies educational inequality in longevity by gender in 23 OECD countries focusing on ages 25 and

and long run for males while for females they are null. For Italy, Cipollone and Rosolia (2011) estimates that increasing the number of graduates by one percent point reduces subsequent 10-years mortality rates by $0.1 - 0.2$ percentage points among males.

[5] Case and Deaton (2015) is also seminal in providing evidence of the decline of 45-54 years old within a general trend of longevity improvements, so called *mortality reversal*. Between 1999-2013, this downward trend in longevity characterised Non-Black Non-Hispanic Americans, especially among those with less education. In particular, causes of death as cyrrhosis, poisoning, suicide, drug and chronic-liver diseases increased. As suggested by Auerbach et al. (2017), this is mainly due opioid epidemic and economic distress.

65. In particular, among individuals aged 25 (65), results that gap in life expectancy between highly and poorly educated is 8 (3.5) years for men and 5 (2.5) years for women.
Focusing on Italy, empirical evidence on life expectancy heterogeneity by education is less documented due to a scarcer data availability compared to countries like US. Maccheroni (2006) is the first work which analyses dispersion of mortality by geography, gender and education over half century (1950-2000). On this line, Maccheroni (2009) shows how longevity heterogeneity by education evolves across ages 35-65 for the year 2001. Distinguishing between individuals with low and high education, he reports that dispersion in life expectancy is age-decreasing. Luy et al. (2011) addresses the dynamics of the longevity heterogeneity by education in Italy, focusing the analysis over the period 1980-1994. They find higher dispersion among men than among women, and confirms that improvements in life expectancy are higher for individuals with tertiary education. Instead, Mazzaferro et al. (2012), with microsimulated data differentiated by gender and three-levels of education during the period 1975-2000, assesses the redistributive features of the Italian public pension system in terms of ratio between net present value of pension benefits and contributions. He concludes that the actual design implies a regressive distribution from men to women, from less educated to more educated and from poor to rich individuals[6]. Unfortunately, none of these works focus their analyses on pre-crises period.
A general limitation for mortality data by education is that there is no direct link to previous education in their death certificate. Usually census data and mortality tables are linked to track those who died and for which the level of education is known at the time of death. Unfortunately, for Italy, ISTAT stopped linking death cerfiticates after the census of 1991 Luy et al. (2011). Since 2016, linking 2011 census data with death occurring during the years 2012-2014, new information on the evolution of life expectancy by education can be exploited for the first time. In fact, apart from Mackenbach et al. (2016), no work considers the years after 2007 even if only the city of Turin is considered in the study. Other works that document life expectancy heterogeneity in Italy during a post-2007 time period are Maccheroni and Nocito (2017) and Lallo and Raitano (2018). But while Maccheroni and Nocito (2017) uses ISTAT mortality tables for 1975-2015 to compare mod-

[6] Also Belloni and Maccheroni (2013) shows that the Italian public pension system violates actuarial fairness if inequality in longevity continues to raise.

els of mortality forecasts, Lallo and Raitano (2018) analyses inequality in longevity by occupation limited to the period 2005-2009. Using newly available ISTAT data for the year 2012, this work is the first that documents dispersion in longevity by education for the last decade.

Moreover, like Maccheroni (2006) and Mazzaferro et al. (2012), this work relates the heterogeneity in longevity to the actuarial fairness of the Italian public pension system. In doing so, it follows Ayuso et al. (2017*b*) and Ayuso et al. (2018) that propose a preliminary evaluation framework. They translate deviations in life expectancy along a particular socioeconomic dimension into tax/subsidy profiles implicitly created when pension annuities are calculated based on a homogeneous value for longevity at retirement. Afterwards, following Ayuso et al. (2017*a*) and Holzmann et al. (2017), tax/subsidy rates are used to compute the intensity of the transfer mechanism for Italy.

Recently, the literature has also discussed (Ayuso et al., 2017*a*) and analysed (Holzmann et al., 2017) possible corrective policies, highlighting their pros and cons. A distinction is made among interventions occurring pre-retirement during the accumulation phase, at retirement during the calculation phase, or post-retirement during the payment phase. They conclude that, in principle, interventions at retirement is desirable since the socioeconomic status, e.g. the level of education, varies negligibly thereafter. Indeed, one advantage of using education as proxy for socioeconomic status is that, unlike other dimensions like income, it is very stable over the entire post-graduate lifetime and not only just after to retirement. Accordingly, considering also that the implicit tax/subsidy mechanism triggers at retirement since the systematic heterogeneity is not considered when pension annuities are computed, a correction at this phase seems to be more appropriate. As an exercise, a gender-differentiation is compared to the standard, unconditional, case.

3 Data

This work exploits newly available ISTAT data on mortality differentials by education for the years 2012-2014 for Italy. This dataset, available since June 2017, is obtained by linking census data of the 2011 wave, from which information about education are taken, with death certificates for the years 2012-2014.

Figure 2 reports the profile of life expectancy by gender and by education for ages $0-90+$ by distinguishing among individuals with at most primary education (I), lower and upper secondary (II_L and II_H) and tertiary education (III). It reveals that differences in longevity by education at birth are the most pronounced. Values for males (females) are 77.2 (83.2), 79.4 (84.6), 80.9 (85.3) and 82.4 (85.9) for the sub-population with at most primary education, lower and upper secondary and tertiary respectively.

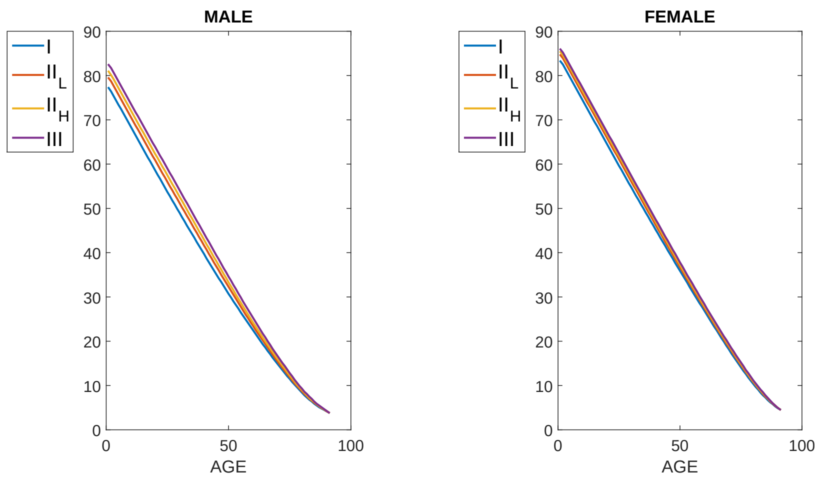

Figure 2: *Life expectancy for male (left) and female (right) for ages 0-90+ for years 2012-2014 by educational levels: at most primary (I), lower and upper secondary (II_L, II_H) and tertiary (III). Source: ISTAT (2017).*

At age 25, dispersion decreases but differentials are still sizeable. Males (females) with less than primary education have a residual life expectancy of 53 (59) years, those with low secondary education of 55 (60) years, those with upper secondary education of 56.5 (61) years and those with tertiary education of 58 (61.5) years. The same figures, at age 65, are of 18 (21.5) years among those with at most primary education, of 18.5 (22) and 19 (22.5) years for those with lower and upper secondary education, respectively, and of 20 (23) years for those with tertiary education. Overall, as reported in figure 3, life expectancy heterogeneity by education has an age-decreasing profile for both genders. Before age 80, life expectancy results to be more dispersed across educational levels. It goes from 2.18 (1.16) years for men (women) at birth, to 0.97 (0.56) years at age 65. After age 75 they coincide.

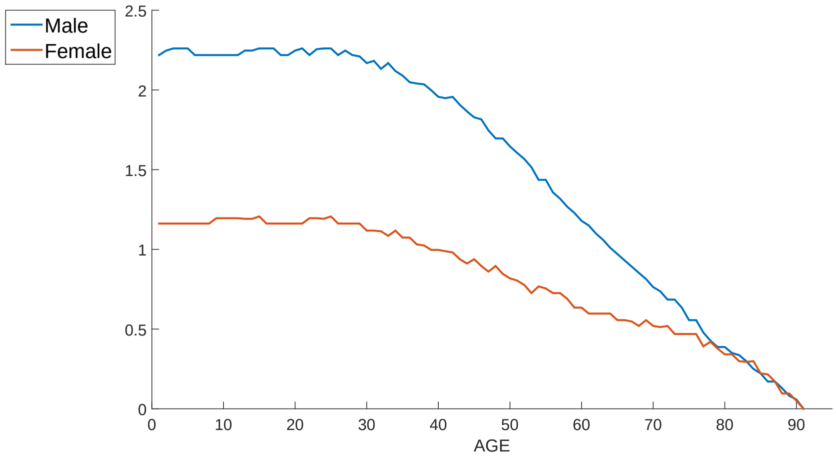

Figure 3: *Standard deviations of life expectancy by education for male and female by age during the years 2012-2014. Source: author's own calculations on data from ISTAT (2017).*

Note also that gender-gap in life expectancy, measured as value for female minus value for male for each educational group, reduces also for higher levels of education by age. In fact, among those aged 25, gender-gap reduces from 6 to 3.5 years when one considers from the least to the most educated group. Among individuals aged 65, it is stable around 3.5 years and decreases to 3 years for those with tertiary education.
Focusing on life expectancy heterogeneity at retirement, proxied at age 65, next section retrieves corresponding tax/subsidy profiles for each educational level and gender. It then quantifies the intensity of the implicit transfer mechanism and compares it with the case of gender-differentiation. Finally, result are extended to lower ages, e.g. 57-64, in order to explore possible age patterns in the intensity of the tax/subsidy mechanism.

4 Results

4.1 Tax/Subsidy Rate: Unconditional Profiles

Following Ayuso et al. (2017*b*), Ayuso et al. (2017*a*), Ayuso et al. (2018) and Holzmann et al. (2017), tax/subsidy rates are computed for each education-by-gender group as deviation of life expectancy of that particular group from the average value adopted at population level. Let LE be the value of (average) life expectancy for the whole population aged 65 during the years 2012-2014, and let $LE_{g,e}$ be the same quantity for the subpopulation of gender g and educational level e. The associated tax/subsidy rate $\tau_{g,e}$ at age 65 is then computed as:

$$\tau_{g,e} = \frac{LE_{g,e}}{LE} - 1 \tag{1}$$

where $g = M, F$ indexes gender and $e = I, II_L, II_H, III$ indexes the level of education. Negative values of $\tau_{g,e}$ indicates that individuals aged 65 with gender g and educational level e pays a tax of rate $|\tau_{g,e}|$ when pension annuities are computed. Since, ex-post, group g, e systematically lives shorter than assumed at retirement, actuarial fairness would imply that conversion factor for pension annuity should have been $|\tau_{g,e}|$% higher than standar imputed. In the opposite case, i.e. $\tau_{g,e} > 0$, that subgroup receives a subsidy.
As figure 4 shows, while male profile is negative for any educational levels, the opposite is true for female[7]. Moreover, the tax/subsidy for male/female rate reduces/increases for higher levels of education.

[7] Also Mazzaferro et al. (2012) finds that the transfer rate is negative for men and positive for women independently on the level of education.

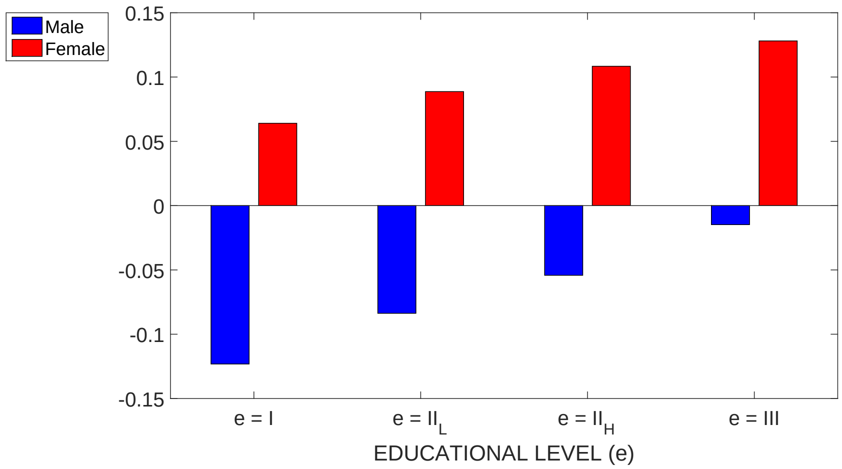

Figure 4: *Tax/Subsidy rate $\tau_{g,e}$ for male and female aged 65 in the years 2012-2014 by education. Source: author's own calculations on data from ISTAT (2017).*

Male (female) with $e = I$ pays a tax (receives a subsidy) of 12.32% (6.4%), followed by individuals having $e = II_L$ and $e = II_H$ with 8.37% and 5.42% (8.87% and 10.84%) respectively. Whereas men (women) with tertiary education pay (receive) the lowest (highest) tax (subsidy), i.e. $\tau_{M,III} = -1.48\%$ ($\tau_{F,III} = 12.81\%$).

4.2 Tax/Subsidy Rate: Gender-differentiated Profiles

The case of gender-differentiation is now considered as a corrective intervention. Accounting for differences in life expectancy by gender is expected to reduce, *sic et simpliciter*, the intensity of the tax/subsidy mechanism at retirement since controlling for gender-related differences silent the channel of heterogeneity due to gender-related factors. As discussed by Ayuso et al. (2017*b*) and Holzmann et al. (2017), intervention at retirement is desirable since information about health status and past work career are known with less uncertainty. Operatively, it is easily implementable, perfectly verifiable and less subject to manipulation at individual level[8]. On the other

[8]The choice of gender as differencing variable is not by chance. Not all socioeconomic factors are equivalently taxable without expecting any reaction from individuals involved

side, one should bear in mind that pension reforms implementing a gender-differentiation in the pension formula are likely to have an effect on labour careers of female individuals[9]. Thus, computation of pensions would be conditional on the gender of the retired individual.
Indicating with $\tilde{\tau}_{g,e}$ the tax/subsidy rate for the group of gender g and educational level e under the gender-differentiated regime, it results:

$$\tilde{\tau}_{g,e} = \frac{LE_{g,e}}{LE_g} \tag{2}$$

where LE_g indicates the value of life expectancy at age 65 for gender $g = M, F$ and $e = I, II_L, II_H, III$ indexes the educational level. Graphically, figure 5 depicts these results.

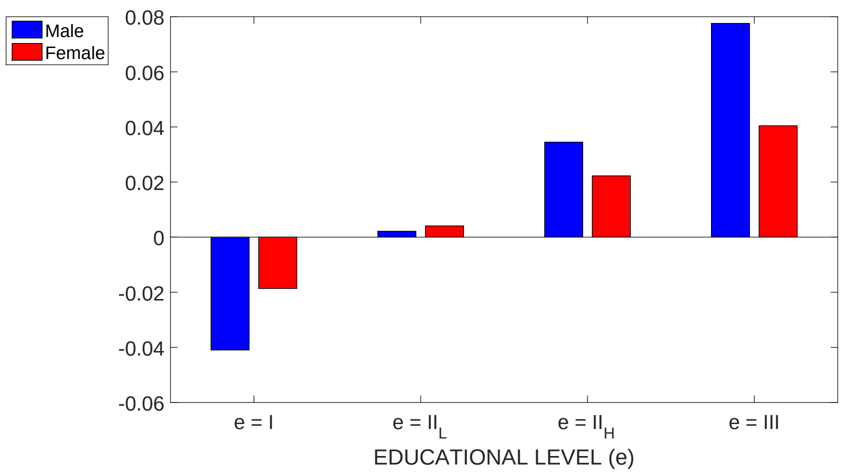

Figure 5: *Gender-differentiated tax/Subsidy rate* $\tilde{\tau}_{g,e}$ *for male and female aged 65 in the years 2012-2014 by education. Source: author's own calculations on data from ISTAT (2017).*

As expected, compared to the unconditional scenario in figure 4, differentiated tax/subsidy rates $\tilde{\tau_{g,e}}$ are lower for any educational level e. Only

in the mechanism. In fact, some factors are strategically manipulable at individual level (e.g. income, geography), some others are less manipulable (e.g. education, marital status) or even hard to be manipulated for economic incentives (e.g. gender, ethnicity).

[9]What is expected, at least among the most sensible under *ceteris paribus* conditions, is that an increase in (effective) taxation is likely to make their labour supply lasting longer.

the subgroup with at most primary education ($e = I$) would pay a tax, of -4.09% if male and -1.86% if female. All other educational groups, both men and women, are subsidised by the implicit transfer mechanism at a rate that increases along educational levels[10]. Individuals with lower secondary education ($e = II_L$) are slightly subsidised (0.22% for men, 0.41% for women) if compared to those with upper secondary education (3.45% for men and 2.23% for women) and, even more, to those with tertiary education (7.76% for men, 4.04% for women).

4.3 TATSI Analysis

Once tax/subsidy profiles at age 65 are computed both for the unconditional tax/subsidy rate $\tau_{g,e}$ (equation 1) and the corresponding gender-differentiated version $\tilde{\tau}_{g,e}$ (equation 2), it is possible to measure and compare the intensity of the transfer mechanism under these two regimes for the years $2012-2014$. At this aim, the Total Absolute Tax/Subsidy Index (TATSI, proposed by Ayuso et al. (2017*a*) and Holzmann et al. (2017)) is computed. Indicating with $TATSI_g$ and $\widetilde{TATSI}_g$ the value of the index for gender g under the unconditional and the gender-differentiated case respectively, they are defined as the sum of absolute values over the corresponding socioeconomic dimension, i.e. education. Thus:

$$TATSI_g = \sum_e |\tau_{g,e}| \tag{3}$$

and

$$\widetilde{TATSI}_g = \sum_e |\tilde{\tau}_{g,e}| \tag{4}$$

where g stands for Male ($g = M$) and Female ($g = F$), while $e = I, II_L, II_H, III$ indexes the level of education. Results are reported in table 1, where characteristics of each profile are compared in terms of intensity ($TATSI$), average rate (AVG) and standard deviation (STD).

[10] Also Mazzaferro et al. (2012) shows that, once gender differences are net out, only male and female with less than upper secondary education, corresponding in this work to individuals with $e = I, II_L$, would pay a tax.

Profile	$e = I$	$e = II_L$	$e = II_H$	$e = III$	$TATSI$	AVG	STD
$\tau_{M,e}$	-0.1232	-0.0837	-0.0542	-0.0148	0.2759	-0.069	0.0459
$\tau_{F,e}$	0.064	0.0887	0.1084	0.1281	0.3892	0.0973	0.0274
$\tilde{\tau}_{M,e}$	-0.0409	0.0022	0.0345	0.0776	0.1552	0.0183	0.0502
$\tilde{\tau}_{F,e}$	-0.0186	0.0041	0.0223	0.0404	0.0854	0.012	0.0253

Table 1: *Comparison between unconditional and gender-differentiated tax/subsidy rates, τ_g and $\tilde{\tau}_g$, for $g = M, F$ for the Italian population aged 65 in 2012: intensity (TATSI), average rate (AVG) and dispersion (STD). Source: author's own calculations on data from ISTAT (2017).*

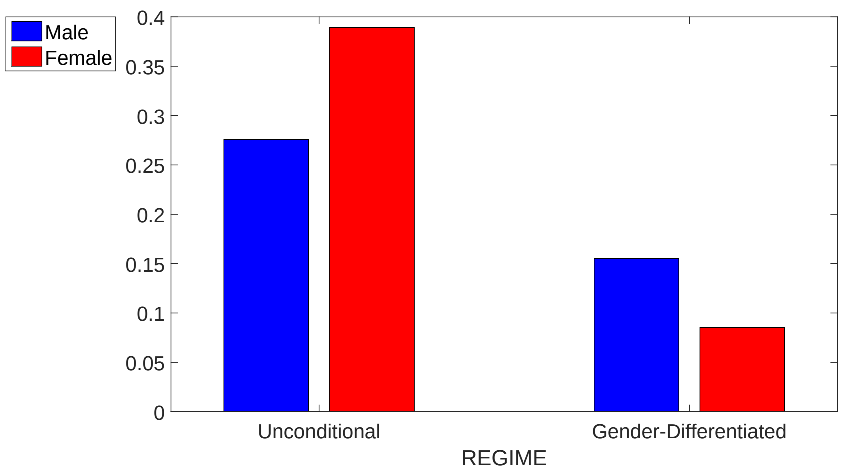

Figure 6: *Comparison between the unconditional case ($TATSI_g$) and gender-differentiated case ($\widetilde{TATSI}_g$) for Italy by gender $g = M, F$ at age* 65 *in years* $2012 - 2014$. *Source: author's own calculations on data from ISTAT (2017).*

As shown also in figure 6, the intensity of the unconditional transfer mechanism is higher than that of the gender-differentiated case both for male, reducing from 0.2759 to 0.1552, and female, reducing from 0.3892 to 0.0854. Once gender differentials in life expectancy are controlled for, the intense of the implicit transfer triggered by differences in longevity education is massively reduced. It is easy to see that from table 1 that, when controlling by gender, the average rate reduces in absolute value. Compared to the unconditional scenario, the average rate for men increases from -6.9% to 1.83%, while that for women reduces from 9.73% to 1.2%. Despite this beneficial effect on the level, and thus on the intensity of the transfer mechanism, no reduction in dispersion emerges from this differentiation. Indeed, when gender-differentiation applies, dispersion slightly increases for male, from 0.0459 to 0.0502, but decreases for female, from 0.0274 to 0.0253. Factors other than gender, e.g. related to labour market, may explain the position reversal in terms of dispersion between male and female.

4.4 Tax/Subsidy Profiles and TATSI for ages 57-65

The analysis so far conducted has focused on a single retirement age, i.e. age 65. Results are now extended to lower ages, e.g. 57-64. This exercise allows to retrieve an age profile for tax/subsidy rates and the intensity of the transfer mechanism. Indeed, figure 7 shows that the effective retirement age, computed for each year as weighted average over previous five years, has always been lower than age 65 throughout the period 1970-2016.

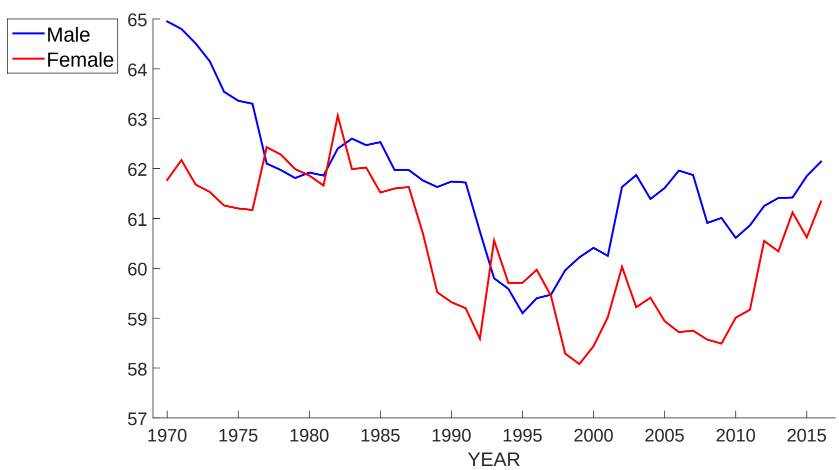

Figure 7: *Effective retirement age in Italy during 1970-2016 for male and female. Source: OECD (2018).*

From 1970 until 1995 male (female) exhibits a decreasing time trend from 65 (62) in 1970 to 59 (60) in 1995. Since 1996, the year in which the defined-contribution pension regime phased-in, the trend reverts and increases in 2016 to 62 (61).. Note also that the gender gap reduces after 2012 as effect of ad hoc reforms. For what concerns, figure 7 allows to claim that the age range considered, i.e. $57-65$, is representative over more than four decades. Following the logic of equations (1) and (2), unconditional and gender-differentiated tax/subsidy rates $\tau_{a,g,e}$ and $\tilde{\tau}_{a,g,e}$ for individuals aged a of gender g and educational level e are given by:

$$\tau_{a,g,e} = \frac{LE_{a,g,e}}{LE_a} \tag{5}$$

and

$$\tilde{\tau}_{a,g,e} = \frac{LE_{a,g,e}}{LE_g} \tag{6}$$

where $LE_{a,g,e}$ refers to the life expectancy at age a for the subgroup g, e. While LE_a and LE_g indicate the value of life expectancy at population level for age a, with $a \in [58, 65]$ and gender $g \in [M, F]$, respectively. Figure 8 reveals that the policy of gender-differentiation of longevity factor not only reduces for all ages a the rates at which retirees aged a are implicitly taxed/subsidised when their pensions are computed, but also flattens the age-profile of the transfer mechanism.

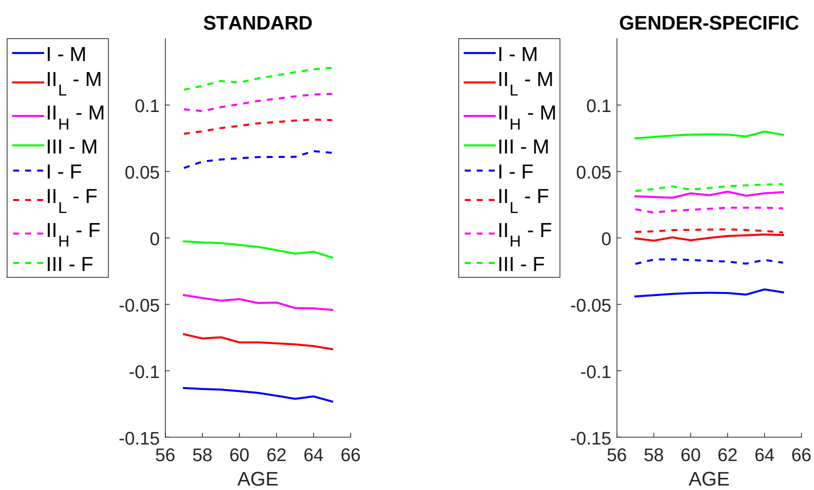

Figure 8: *Comparison between standard (left) and gender-diffentiated (right) tax/subsidy profiles by age, gender and education during the yers 2012-2014 in Italy. Source: author's own calculations on data from ISTAT (2017).*

In particular, focusing on the unconditional case on the left panel of figure 8, it is easy to see that educational profiles of males (females) exhibit a slightly

age-decreasing (age-increasing) trend. This implies that results provided for men (women) at age 65 represent a lower (upper) bound for younger ages and an upper (lower) bound for older ones. Instead, on the right panel of figure 8, gender-differentiated profiles $\tilde{\tau}_{a,g,e}$ exhibit no particular gender-specific trend in the age range $57 - 65$.
Moving to the analysis of the intensity of the tax/subsidy mechanism, the age-specific value of TATSI is defined as absolute sum over education among individuals with age a and gender g. Similar to equations (3) and (4), the unconditional and gender-differentiated TATSI are defined by:

$$TATSI_{a,g} = \sum_{e} |\tau_{a,g,e}| \tag{7}$$

and

$$\widetilde{TATSI}_{a,g} = \sum_{e} |\tilde{\tau}_{a,g,e}| \tag{8}$$

where $\tau_{a,g,e}$ and $\tilde{\tau}_{a,g,e}$ are defined in equations (5) and (6) respectively. Figure 9 reports the age pattern of TATSI (in education) by gender and pension calculation regime. It confirms that the implicit transfer mechanism is more intense for female than for male, and it becomes more intense for both genders when age increases from 57 to 65.

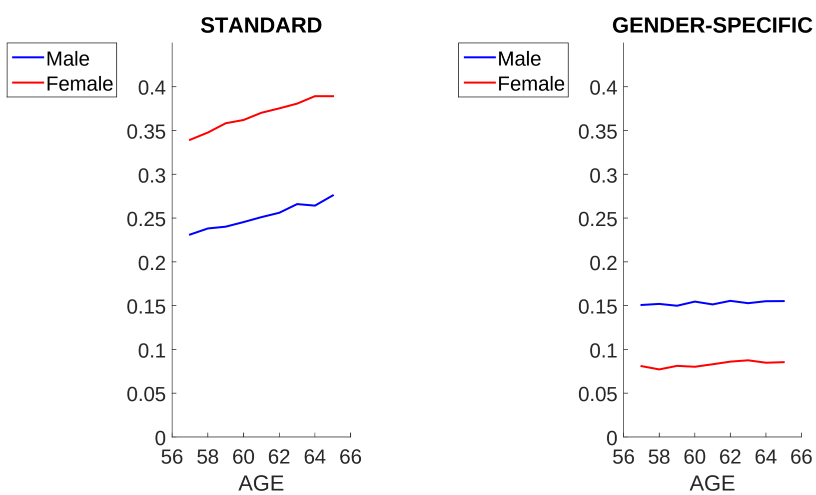

Figure 9: *Comparison between intensity of TATSI values for male and female across ages 57-65 under the standard (left) and the gender-differentiated regime (right) for Italy in years 2012-2014. Source: author's own calculations on data from ISTAT (2017).*

Under the standard scenario, where pension formula is based on a homogeneous factor for longevity, TATSI increases for male (female) from 0.2311 (0.3393) to 0.0.2759 (0.3892) when age moves from 57 to 65. Under the gender-differentiated regime, it remains around 0.15 (0.08), precisely increasing from 0.1507 (0.0809) at age 57 to 0.1552 (0.0854) at age 65.

5 Conclusions

This aim of this work is document the persistence in life expectancy heterogeneity by education in Italy using recently available ISTAT data for the period $2012 - 2014$. It shows that while men are taxed across all levels of education, female are subsidised. Instead, when differences in longevity by gender are explicitly considered in the computation of pension annuities, the intensity of the tax/subsidy mechanism considerably lowers. Under this gender-differentiated regime, only individuals aged 65 with at most primary education pay a tax. Such results are confirmed for also ages $57 - 64$. Moreover, in this case, tax/subsidy rates decrease with age among males but increases among females. The intervention of gender-differentiation would neutralise these trends.

The proposed intervention, i.e. a gender-differentiation of longevity factors in the computation of pension annuities, seems to be fruitful. Certainly, tax Italian women for their longer lives is not the final remedy to restore actuarial fairness in the Italian public pension system. Considering their situation in the labour market, female is less employed and under paid in European countries compared to the male counterpart. Only a more complete analysis, possibly integrating labour market and pension concerns, can really assess its overall impact.

In conclusions, the presence of an increasing trend by age in the intensity of the tax/subsidy profile calls for more attention when raises of retirement age are legislated. When a higher retirement age is promoted, one should be aware of the consequences in terms of reduced actuarial fairness of the Italian pension system, i.e. on the exacerbation of the tax/subsidy mechanism in place. This warn follows Auerbach et al. (2017) for US, Whitehouse and Zaidi (2008) and Ayuso et al. (2017*a*) for OECD countries. If, as often the case, the level of education positively correlates with income, then also the progressivity of public pension systems are reduced (Ayuso et al., 2017*a*,*b*;

Mazzaferro et al., 2012). Neglecting such heterogeneity may also seriously bias projections of pension expenditures and, thus, the timing of reforms (Ayuso et al., 2018; Belloni and Maccheroni, 2013).
Further research is needed to make the tax/subsidy mechanism more transparent and regularly monitored. Moreover, particular stress must be given to labour market, which may help to explain particular trends in some countries. For example, appendix A provides empirical suggestive evidence of a negative relation between skills mismatch and longevity heterogeneity by education across ages for a pool of European countries in 2015. A richer evidence is needed not only to corroborate this conclusion, but also to highlight the role of labour market institutions having an impact longevity dispersion across education and other relevant socioeconomic dimensions. This would be another example of the interplay between labour market and pension systems.

References

Auerbach, A. J., Charles, K. K., Coile, C. C., Gale, W., Goldman, D., Lee, R., Lucas, C. M., Orszag, P. R., Sheiner, L. M., Tysinger, B. et al. (2017), 'How the growing gap in life expectancy may affect retirement benefits and reforms', *The Geneva Papers on Risk and Insurance-Issues and Practice* **42**(3), 475–499.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*a*), 'Addressing longevity heterogeneity in pension scheme design', *Journal of Finance and Economics* **6**(1), 1–21.

Ayuso, M., Bravo, J. M. and Holzmann, R. (2017*b*), 'On the heterogeneity in longevity among socioeconomic groups: Scope, trends, and implications for earnings-related pension schemes', *Global Journal of Human-Social Science Research* **17**(1), 37–58.

Ayuso, M., Bravo, J. M., Holzmann, R. et al. (2018), 'Getting life expectancy estimates right for pension policy: Period versus cohort approach', *Institute for the Study of Labor (IZA)* (11512).

Belloni, M. and Maccheroni, C. (2013), 'Actuarial fairness when longevity increases: An evaluation of the italian pension system', *The Geneva Papers on Risk and Insurance-Issues and Practice* **38**(4), 638–674.

Case, A. and Deaton, A. (2015), 'Rising morbidity and mortality in midlife among white non-hispanic americans in the 21st century.', *Proceedings of the National Academy of Sciences of the United States of America* **112**(49), 15078–15083.

Cipollone, P. and Rosolia, A. (2011), *Schooling and youth mortality: learning from a mass military exemption*, The World Bank.

Elo, I. T. and Preston, S. H. (1996), 'Educational differentials in mortality: United states, 1979–1985', *Social science & medicine* **42**(1), 47–57.

Fawcett, J., Blakely, T. and Kunst, A. (2005), 'Are mortality differences and trends by education any better or worse in new zealand? a comparison study with norway, denmark and finland, 1980–1990s', *European Journal of Epidemiology* **20**(8), 683–691.

Gathmann, C., Jurges, H. and Reinhold, S. (2015), 'Compulsory schooling reforms, education and mortality in twentieth century europe', *Social Science & Medicine* **127**, 74–82.

Holzmann, R., Alonso-Garcia, J., Labit-Hardy, H. and Villegas, A. M. (2017), Ndc schemes and heterogeneity in longevity: Proposals for redesign, Technical Report 11193.

Holzmann, R. and Palmer, E. (2006), *Pension reform: issues and prospects for non-financial defined contribution (NDC) schemes*, The World Bank.

Kitagawa, E. M. and Hauser, P. M. (1973), 'Differential mortality in the united states: A study in socioeconomic epidemiology'.

Lallo, C. and Raitano, M. (2018), 'Life expectancy inequalities in the elderly by socioeconomic status: evidence from italy', *Population Health Metrics* **16**(1), 7.

Luy, M., Di Giulio, P. and Caselli, G. (2011), 'Differences in life expectancy by education and occupation in italy, 1980–94: Indirect estimates from maternal and paternal orphanhood', *Population studies* **65**(2), 137–155.

Maccheroni, C. (2006), 'La mortalità differenziale: un fattore demografico di cui la riforma del sistema previdenziale non tiene conto adeguatamente', *Quaderni Europei sul Nuovo Welfare* (5), 76–84.

Maccheroni, C. (2009), 'Una stima della speranza di vita per grado d'istruzione in italia all'inizio degli anni 2000', *Polis* **13**(1), 127–142.

Maccheroni, C. and Nocito, S. (2017), 'Backtesting the lee–carter and the cairns–blake–dowd stochastic mortality models on italian death rates', *Risks* **5**(3), 34.

Mackenbach, J. P., Kulhanova, I., Artnik, B., Bopp, M., Borrell, C., Clemens, T., Costa, G., Dibben, C., Kalediene, R., Lundberg, O. et al. (2016), 'Changes in mortality inequalities over two decades: register based study of european countries', *bmj* **353**, i1732.

Mackenbach, J. P., Kunst, A. E., Groenhof, F., Borgan, J.-K., Costa, G., Faggiano, F., Jozan, P., Leinsalu, M., Martikainen, P., Rychtarikova, J. et al. (1999), 'Socioeconomic inequalities in mortality among women and among men: an international study.', *American Journal of Public Health* **89**(12), 1800–1806.

Mazzaferro, C., Morciano, M. and Savegnago, M. (2012), 'Differential mortality and redistribution in the italian notional defined contribution system', *Journal of Pension Economics & Finance* **11**(4), 500–530.

Meara, E. R., Richards, S. and Cutler, D. M. (2008), 'The gap gets bigger: changes in mortality and life expectancy, by education, 1981–2000', *Health Affairs* **27**(2), 350–360.

Miech, R., Pampel, F., Kim, J. and Rogers, R. G. (2011), 'The enduring association between education and mortality: the role of widening and narrowing disparities', *American Sociological Review* **76**(6), 913–934.

Murphy, M., Bobak, M., Nicholson, A., Rose, R. and Marmot, M. (2006), 'The widening gap in mortality by educational level in the russian federation, 1980–2001', *American Journal of Public Health* **96**(7), 1293–1299.

Murtin, F., Mackenbach, J., Jasilionis, D. and d'Ercole, M. M. (2017), 'Inequalities in longevity by education in oecd countries', *OECD Statistics Working Papers* (2).

Oeppen, J. and Vaupel, J. W. (2002), 'Broken limits to life expectancy.(policy forum: Demography)', *Science* **296**(5570), 1029–1031.

Preston, S. H. and Elo, I. T. (1995), 'Are educational differentials in adult mortality increasing in the united states?', *Journal of aging and health* **7**(4), 476–496.

Van Raalte, A. A., Kunst, A. E., Deboosere, P., Leinsalu, M., Lundberg, O., Martikainen, P., Strand, B. H., Artnik, B., Wojtyniak, B. and Mackenbach, J. P. (2011), 'More variation in lifespan in lower educated groups: evidence from 10 european countries', *International Journal of Epidemiology* **40**(6), 1703–1714.

Whitehouse, E. (2007), 'Life-expectancy risk and pensions: who bears the burden?', *OECD Social, Employment, and Migration Working Papers* (60).

Whitehouse, E. R. and Zaidi, A. (2008), 'Socio-economic differences in mortality', *OECD Social, Employment, and Migration Working Papers* (71).

A Skills mismatch and longevity heterogeneity by education: suggestive evidence of a negative relation

This appendix provides suggestive evidence of a negative relation between skills mismatch and dispersion of life expectancy by education for the year 2015. Using OECD data on skills mismatch and EuroStat data on heterogeneity in longevity by education for the year 2015, a pool of six European countries is considered. Countries are Denmark, Finland, Greece, Italy, Portugal and Sweden.

For each country, figure 10 shows the dispersion (standard deviation) of life expectancy by educational attainments from age 25 to age 85+. Firstly, note that longevity heterogeneity by education sharply reduces after age 55 and it is negligible after age 75, which reflects on the role of education discussed in this work. Secondly, with respect other countries in the pool, Italy and Sweden (and their unfunded defined-contribution public pension system) feature the lowest profiles. This allows considering main results of this work as a lower bound in an European cross-crountry perspective.

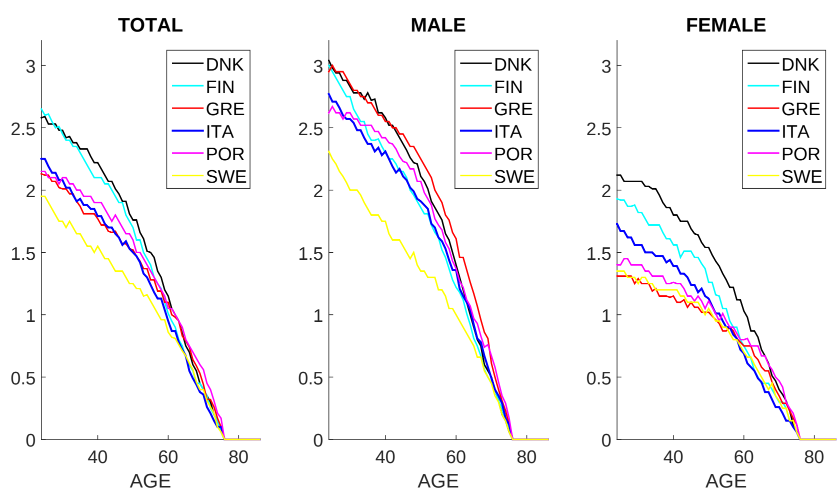

Figure 10: *Dispersion of life expectancy by education from age* 25 *to* 85+ *for the total (left), male (center) and female (right) population in the year* 2015 *for a pool of European countries. Source: EuroStat (2017).*

Thirdly, male profile is higher than that of female reflecting also a gender-specific effect of labour market. Fourthly, among males, unhealthy habits like smoking and drinking may explain why Italy and Sweden but also Finland show the lowest age profile for educational dispersion in life expectancy. That is, unhealthy lifestyles dissipate the gain in life expectancy obtained from a higher education.

Focusing on the interplay between labour market and pension systems, this appendix reports evidence of a negative relaton between skills mismatch in the labour market and dispersion of life expectancy by education across different ages. Increasing the randomness of job-worker matching dissipates the role of education in shaping the inequality in longevity also at retirement. If the degree of randomness between jobs and worker's skills increases, also improvements in life expectancy associated to human capital are more randomly distributed across workers employed in different jobs despite the same level of education/skills. This mechanism, inner to the labour market, produces a positive externality towards the public pension system. In fact, at retirement, a higher level of skills mismatch would reduce the intensity of the tax/subsidy mechanism studied in this work. Hence, a negative relation between skills mismatch and longevity heterogeneity by education is tested. At this aim, OECD data on skills mismatch are considered for the year 2015 for the pool of 6 European countries in figure 10. In particular, for each country i, table 2 presents different measures of skills mismatch M_i^{α}. OECD defines horizontal (or field-of-study) mismatch M_i^H as the incidence of workers in occupations (ISCO) not corresponding to the field of study (ISCED-F) they attended. Vertical (or qualification) mismatch M_i^V is the sum between underqualification M_i^{UQ} and overqualification M_i^{OQ}. They refer to the portion of workers employed in occupations requiring a higher and a lower level of education, respectively. Note that countries in Southern Europe like Italy and Portugal and (to a lesser extent) Greece are characterised by a higher degree of horizontal and vertical skills mismatch compared to countries in Norther Europe like Denmark, Finland and (to a lesser extent) Sweden. Note also that, while Southern countries have a lower-than-average incidence of underqualification mismatch compared to Northern countries, the opposite is true in the case of overqualification mismatch.

	M_i^α			
Country i	M_i^H	M_i^V	M_i^{UQ}	M_i^{OQ}
Denmark	29.66	33.76	20.3	13.45
Finland	23.09	28.29	20.94	7.35
Greece	38.65	44.09	20.97	23.13
Italy	35.41	38.75	17.66	21.09
Portugal	34.95	42.71	17.69	25.02
Sweden	35.62	36.8	22.59	14.22
Avg	30.28	34.65	20.71	13.94
Std	4.94	3.25	3.07	4.91

Table 2: *Different measures of skills mismatch M_i^α for the pool of European countries in the year* 2015*: horizontal (M_i^H) and vertical (M_i^V), vertical-underqualification M_i^{UQ} and vertical-overqualification (M_i^{OQ}). Reported statistics are average Avg and standard deviation Std. Source: author's own elaboration on data from OECD (2017).*

Figure 10 and table 2 jointly suggest the idea of a negative relation between skills mismatch and dispersion of life expectancy by education. In particular, looking at Italy and Sweden, it could be the case for Southern as well as Northern Europe countries.
In order to quantify this (linear) association, the Pearson correlation coefficient is computed between each measure of skills mismatch and dispersion of longevity by education across ages $25-75$ for each gender. Figure 11 reports results. Concerning the four measures of skills mismatch considered, note that vertical and overqualification share exactly the same correlation profile by ages, while horizontal mismatch is somehow lower. Results for the total population (top) shows that a negative sign of the correlation coefficient persists until age 60. Afterwards, dispersion of life expectancy by education remains negatively correlated only with underqualification skills mismatch. Also for males (center), only underqualification skills mismatch negatively correlates with longevity dispersion throughout the age range $25-75$. While for females (bottom) all measures of skills mismatch are negatively correlated with dispersion of longevity by education also after age 60, except underqualification whose age profile results to be flat. For each measure of skills mismatch, figures 12-15 report corresponding scatter plots for ages 25-55.

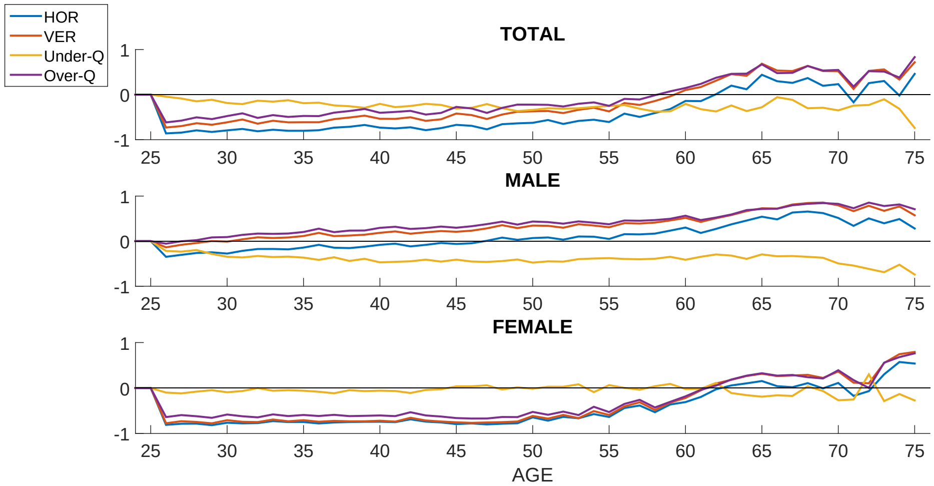

Figure 11: *Age profile of (Pearson) correlation between skills mismatch* $\alpha = H, V, UQ, OQ$ *and dispersion of life expectancy by education for ages* $25 - 75$ *for the total (top), male (center) and female (bottom) population in the year* 2015 *for a pool of European countries. Source: EuroStat (2017).*

Note that correlation coefficients are strong and negative for low and middle ages, which become strong and positive for ages closer to 75.
This preliminary analysis of the age profile of correlation coefficients shows that measuring the relation between skills mismatch and life expectancy heterogeneity at retirement (e.g. age 65) maybe misleading. Indeed, skills mismatch in the labour market negatively affects the dispersion of longevity by education especially for lower ages. This may suggest at least two things. One refers to the role of skills mismatch, which relevant at the beginning of in careers of individuals and somehow dissipate when workers approach to retirement. The other refers to the limitation of having data only for the year 2015. Contemporaneous effect may be stronger for younger workers to then dissipate when they approach to retirement. For example, having data on skills mismatch dated at least 1985 could help to refine this conclusion for those aged 55 in 2015.

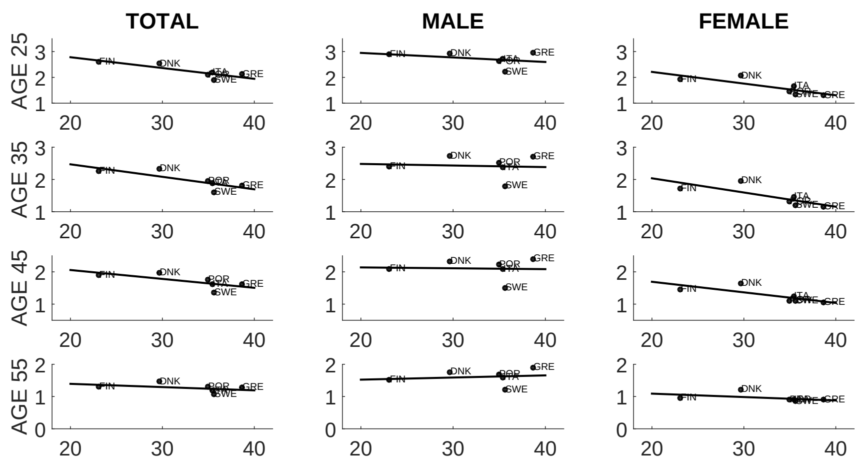

Figure 12: *Horizontal skills mismatch (horizontal axis) vs Dispersion in Life expectancy by education (vertical axis) at age 25 (top), 35, 45 and 55 (bottom). Source: author's own elaboration on data from EuroStat (2017) and OECD (2017).*

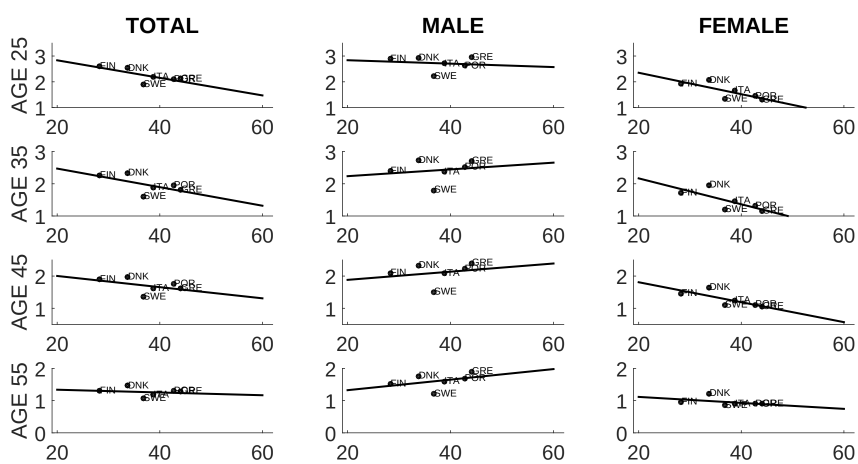

Figure 13: *Vertical skills mismatch (horizontal axis) vs Dispersion in Life expectancy by education (vertical axis) at age 25 (top), 35, 45 and 55 (bottom). Source: author's own elaboration on data from EuroStat (2017) and OECD (2017).*

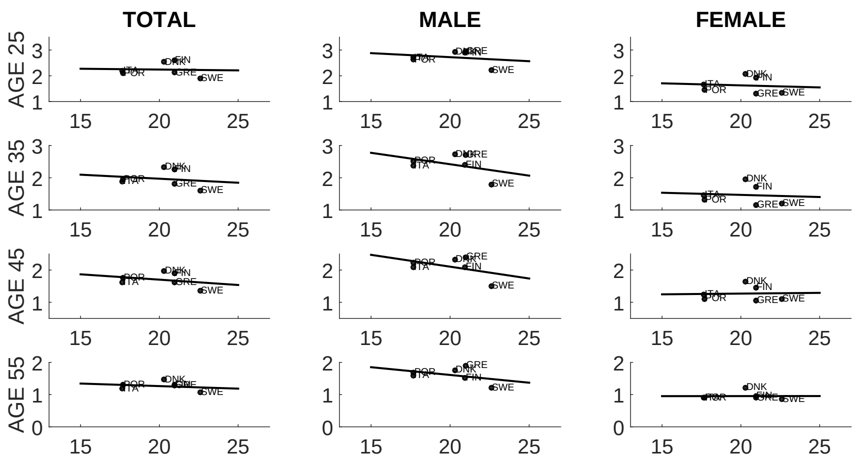

Figure 14: *Underqualification skills mismatch (horizontal axis) vs Dispersion in Life expectancy by education (vertical axis) at age 25 (top), 35, 45 and 55 (bottom). Source: author's own elaboration on data from EuroStat (2017) and OECD (2017).*

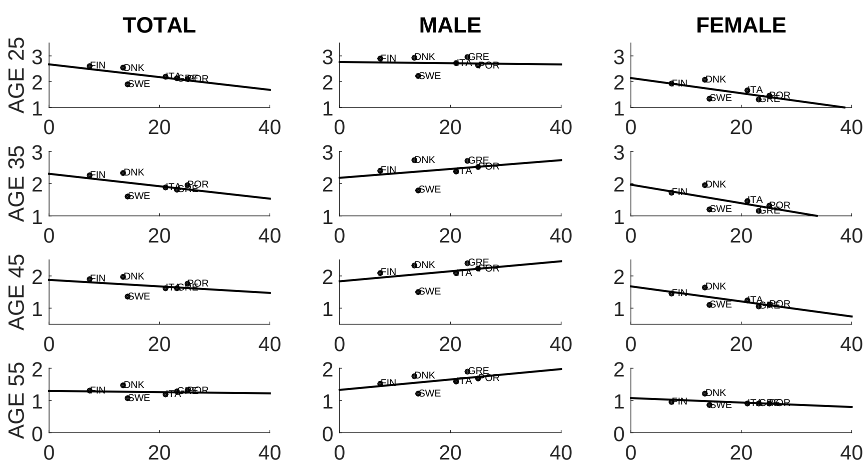

Figure 15: *Overqualification skills mismatch (horizontal axis) vs Dispersion in Life expectancy by education (vertical axis) at age 25 (top), 35, 45 and 55 (bottom). Source: author's own elaboration on data from EuroStat (2017) and OECD (2017).*