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The impact of longevity risk on annuitization factors in the Italian state defined contribution pension scheme

Abstract

In 1995 in Italy notional defined contributions system was introduced in the pay-as-you-go pension pillar. According to this scheme, contributions paid during the working life are accumulated at the expected economic growth rate until the retirement age, when the amount is converted into a life annuity taking into account the forecasted expectancy of life. Longevity risk, due to systematic deviations of the number of the deaths from its expected values, impacts on pension providers or workers depending on when it take place. If life-expectancy improvements occur during the working life, the risk is born by workers. Instead, if life-expectancy improvements occur during the retirement, the risk is born by pension provider. This paper analyzes the current reform of the Italian public pension system and stadies the impact of longevity risk on transformation coefficients, which are applied to accumulate balances in order to convert them into pension benefits. Numerical results show projected coefficients for 2013 using two different stochastic mortality models, the Lee Carter model and the functional demographic model.

Keywords: defined contribution scheme, longevity risk, pension system, retirement, transformation coefficient.

Introduction

In the 20th century, the human mortality has decreased globally. Such trends in mortality reduction have to be taken into account by governments and financial services providers when they define pension rules in terms of retirement ages, contributions paid during the working life, benefits paid to pensioners. Pensions are long-term contracts between pension providers, such as governments or private pension funds and pensioners, and due to their long-term horizon they are consistently affected by both financial and longevity risk. In order to estimate the pension expenditure, an important information is the forecast of remaining life expectancy of pensioners. It is influenced by the longevity risk, that derives from improvements in mortality trend, which determine systematic deviations of the number of deaths from its expected values. Thus, reasonable mortality forecasting techniques have to be used to consistently predict the mortality trends.

Population ageing has implications on sustainability of pension systems, which need to be reformed. Governments have acted in recent years to find more sustainable pension systems. Against the background of ageing populations, due to rising longevity, governments will find it increasingly difficult to maintain current state pension policies. They are setting up pension schemes, contribution rates, benefit indexations and retirement ages so that the resources accumulated during the working life are sufficient to ensure the payments promised to pensioners. Increasing the effective working life is a natural way to limit the social burden of financing public pension system. In addition, in many countries current legislations are furthering a gradual shift from defined benefits (DB) to defined contributions (DC) system. DB plan sponsors promise a specific cash benefit to a worker upon retirement, with the benefit depending upon such factors as years of service and salary. Under DC plans, the plan sponsor agrees only to make contributions to the worker's retirement fund. The ultimate value of the retirement "benefit" under a DC plan varies with the amount of contributions from the employer and worker, as well as investment performance. DC plans differ on how much control the worker has over investment policy, but the worker usually bears most of the risks and rewards associated with variable investment performance. The shift from DB to DC pension plans is a global phenomenon. To have an idea of it, we focus mainly on organization for economic co-oparation and development (OECD) countries because the data are readily available, however, there has been considerable growth in the DC pension sector outside the OECD. Within the OECD, Denmark, Ireland and Spain have already accumulated over 90 per cent of pension sector assets in DC plans; Iceland, Austria and Italy over 70 per cent; New Zealand over 50 per cent (the data are taken from Pension Market in Focus 2005 and include OECD global pension statistics). In contrast, there are a small number of countries (e.g., Norway), where DB plans remain the dominant form of pension. Moreover, in many established pension systems, a DC or hybrid model has been adopted in other countries that have reformed their pension systems in recent years. Countries that have recently moved to funded occupational pensions (e.g., Spain and Italy within the OECD and Poland, Czechoslovakia and Hungary within eastern Europe) have preferred a system based on DC or hybrid arrangements. Within emerging market countries Malaysia has recently adopted a DC arrangement and Chile and Singapore are noteworthy in having longstanding DC pension systems (see Broadbent et al., 2006). In 1995 in Italy a reform introduced notional defined contributions

(NDC) scheme in the pay-as-you-go (PAYG) pension pillar. According to NDC, pensions are determined on a defined contribution basis, and notionally accumulated contributions are transformed into an annuity at retirement. In particular, contributions paid during the working life are accumulated at the expected economic growth rate until the retirement age. If the forecasting of the GDP growth rate and that of mortality evolution are correct, both the macroeconomic and longevity risks are transferred by pension providers to workers. At retirement, the accumulated capital is converted into an annuity taking account of the average life expectancy through the so-called transformation coefficients or annuitization factors. As it is well known in the actuarial applications, the transformation coefficient converts the amount paid by the policyholder at the inception of the contract into a life annuity so that the actuarial discounted value of all instalments is equal to the amount paid at inception. If this equality is verified, the contract respect the principle of actuarial fairness (see Gronchi and Gismondi, 2010).

The NDC scheme obeys the principle of actuarial fairness (cf. Belloni and Maccheroni, 2006), thanks to the equality between the accumulated contributions and the present value of the pension benefits, both calculated at the retirement age. As consequence, if workers decide to extend their working life, they will obtain a greater pension but for an expected shorter period. In this regards, the choice about the retirement age into the intervals fixed by law becomes an important control variable to set pension benefits in line with consumption needs of pensioners.

In this paper we go over the Italian public pension legislation, focusing on the introduction of NDC, and we study the impact of longevity risk on pension providers and workers. Since the of January 1, 2010, new transformation coefficients are applied to compute pension benefits; further revisions will be made every three years. We offer an estimate of coefficients for 2013, forecasting mortality through two stochastic models. The first one is the widely used Lee Carter model, used by ISTAT (National Institute of Statistics in Italy) to produce Italian mortality forecasts. The second one is an extension of the former, the functional demographic model proposed by Hyndman and Ullah (2005).

The paper is organized as follows. Section 1 presents the current reform of the Italian public pension system. Section 2 describes the Lee Carter model (LC) and the functional demographic model (FDM). Section 3 shows the Italian mortality data, forecasts and the impact of longevity risk on Italian transformation coefficients. Concluding remarks are provided in the last Section.

1. The reform of Italian public pension system

The Italian pension system is characterized by a compulsory public system, financed as a pay-as-you-go system. The public system is subdivided into different schemes for different workers. More than 2/3rds of the public pension system is administered by INPS (Social Security Institute for private sector), about 1/4th of the public pension system is administered by INPDAP (Social Security Institute for the public sector), and the remaining part is administered by a number of small institutions. The public pension expenditure is assigned to old age and early retirement for 70% of the total expenditure, to disability for 13% and to survivors for the remaining 17%; from these data, it is clear that population ageing has implications on sustainability of Italian pension systems. The first reform came in 1992 and raised the retirement ages from 55 to 60 years for women and from 60 to 65 for men in private employment. In addition, the minimum number of years of contributions required for public sector employees raised to 35 years (cf. Franco and Sartor, 2006).

In 1995, Law 335/95 required a shift from DB to NDC scheme, in which notional accumulated contributions on individual accounts are converted into an annuity at retirement. Unlike the preceding method, the latter takes into account the amount of contribution paid throughout the whole working life accumulated at the expected GDP growth rate, the life expectancy of the pensioner at retirement age and the number of years that a survivor's benefit will be withdrawn by any widow or widower, according to actuarial equivalence principle. Different rules are applied to pension computation according to the seniority accrued by workers: new scheme is not applied to workers with at least 18 years of seniority in 1995 while it is fully applied to all who are employed from 1996 onward; the others are treated with a pro rata method.

The NDC formula to compute pension benefits for retirement at age x is the following:

$$P(x) = \left[c_a + \sum_{i=1}^{a-1} c_i \prod_{j=i}^{a-1} (1 + \overline{g}_j) \right] \delta_x, \qquad (1)$$

where c_i is the contribution paid by the worker at seniority i, a is the seniority at retirement (i.e., the number of year of the working life), $\overline{g}_j$ is the geometric mean of nominal GDP growth rate calculated according the observations in the 5 years preceding the year in which seniority is j, δ_x is the transformation coefficient for retirement at age x. The formula comes from the more simple NDC pension schemes, where the contribution paid during the working life are accumulated at the expected GDP

growth rate. The term in brackets represents the total contribution accumulated by worker during the working life. It is transformed into pension benefit by the transformation coefficient δ_x. It is given by the inverse of the expected present value of an unitary annuity revertible to the spouse. Generally, for life annuities or pension products the transformation coefficient is calculated in the following way:

$$\delta_x = \left[\left[\sum_{t=0}^{\Omega-x} E\left[1_{T_{x\geq t}}\right]P_0^{t+1}\right]\right]^{-1}, \quad (2)$$

where T_x is the remaining lifetime for an individual aged x and Ω is the final age at which all pensioners are considered died (in the last mortality tables the final age recorded is 120). We denote $1_{T_{x\geq t}}$ for the indicator random variable that indicates whether an individual with age x at time 0 will survive at least t more years. $E\left[1_{T_{x\geq t}}\right]$ denotes the expected value at $t = 0$ of one unit to be paid at time $t + 1$ if the pensioner is still alive, and P_0^{t+1} denotes the market value of a zero-coupon bond maturing at time $t + 1$ (see Hary et al., 2007). In particular:

$$E\left[1_{T_{x\geq t}}\right] = E\left[{}_t p_x\right] = \frac{l_{x+t}}{l_x}, \quad (3)$$

where ${}_t p_x$ is the survival probability at age $x + t$ conditional on being alive at age x and l_x is the number of survivors at age x.

In the case of the Italian pension scheme, the NDC formulas to compute the transformation coefficients are the following:

$$\delta_x = \left(\frac{\sum_{s=m,f} dir_{x,s} + ind_{x,s}}{2} - \gamma\right)^{-1}, \quad x \in [57,65], \quad (4)$$

$$dir_{x,s} = \sum_{t=0}^{(\Omega-x)} \frac{l_{x+t,s}}{l_{x,s}}\left(1 + g_f\right)^{-t}, \quad (5)$$

$$ind_{x,s} = \theta \sum_{t=0}^{(\Omega-x)} \frac{l_{x+t,s}}{l_{x,s}}\left(1 - \frac{l_{x+t+1,s}}{l_{x+t,s}}\right)\left(1 + g_f\right)^{-(t+1)} a_{x+t+1}^W, \quad (6)$$

where $l_{x,s}$ is the number of survivors at age x for the specific gender s ($s = m$ is "male", $s = f$ is "female"), $\frac{l_{x+t,s}}{l_{x,s}}$ is the survival probability at age $x + t$ conditional on being alive at age x for the specific gender s, $\frac{l_{x+t,s}}{l_{x,s}}\left(1 - \frac{l_{x+t+1,s}}{l_{x+t,s}}\right)$ is the probability for an individual aged x with specific gender s to survive until age $x + t$ and die within one year; γ is an actuarial factor to take into account different frequencies in pension payment and is fixed by law, g_f is the long-run expected GDP growth rate, a_{x+t+1}^W is the expected present value of a unitary annuity paid to the widow or widower at time $x + t + 1$, θ is the quota of pension revertible to the widow or widower. Equation (5) is inspired by equation (2), with the interest rate of the zero coupon bond equal to the expected GDP growth rate. Equation (6) takes into account the pension benefits received by the widow or widower in the case of pensioner's death.

As it is clear from equations (4)-(6), differences between genders are averaged out and transformation coefficients are the same for males and females with the same age. This produce a redistribution of wealth from men, who have a shorter expectancy of life, to women. Other distributive effects of Italian pension system are analyzed by Borrella (2004) and Borrella and Coda (2005).

According to the law 335/95, transformation coefficients are calculated setting $g_f = 0.015$, $\theta = 0.6$, $\gamma = 0.42$ and taking into account the ISTAT1990 mortality table; a_{x+t+1}^W is actualized using a rate $r = 0.015$.

The 1995 reform established that transformation coefficients should have been updated every ten years in order to consider variation in longevity, but the first revision in 2005 did not take place. However, since of January 1, 2010 the new coefficients, set by Law 247/07, are applied and the revision of criteria for determining coefficients will take place every three years. Table 1 shows the transformations coefficients used until 2009 and those introduced since of January 1, 2010.

Table 1. Transformation coefficients

Law	Retirement age								
	57	58	59	60	61	62	63	64	65
335/95	4.72%	4.86%	5.006%	5.163%	5.334%	5.514%	5.706%	5.911%	6.136%
247/07	4.419%	4.538%	4.664%	4.798%	4.94%	5.093%	5.257%	5.432%	5.62%

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[1] Equations (4)-(6) form a simplified version of the formula established by law, which takes into account also the probability for the window(er) to marry again and the reduction in the window(er)'s pension due to her(his) additional income.

Until now we have described the Italian public pension system, henceforth, we aim to study the impact of longevity risk on transformation coefficients. In the following sections, we introduce the Lee Carter model and the functional demographic model, forecast Italian life expectancy and use the projected probabilities to estimate the transformation coefficients for 2013.

2. The Lee Carter model and the functional demographic model

The Lee Carter methodology is a milestone in the actuarial literature of mortality projections. The model describes the log of the observed mortality rate for age x and year t, $m_{x,t}$ as the sum of an age-specific component α_x, that is independent of the time, and another component that is the product of a time-varying parameter k_t, reflecting the general level of mortality, and an age-specific component β_x, that represents how mortality at each age varies when the general level of mortality changes:

$$\ln(m_{x,t}) = \alpha_x + \beta_{x,t} k_t + \varepsilon_{x,t}, \tag{7}$$

where $\varepsilon_{x,t}$ are assumed to be homoskedastic.

This model is fit to historical data via singular value decomposition. The resulting estimate of the time-varying parameter is then modeled as a stochastic process, Box-Jenkins techniques are used to estimate and forecast k_t within an ARIMA time series model, from the forecasted k_t it is possible to forecast mortality rates.

The Lee Carter model (1992) has become widely used and there have been various extensions and modifications proposed to attain a broader interpretation and to capture the main features of the dynamics of the mortality intensity. Hyndman and Ullah (2005) show a particular version of the Lee Carter methodology, the so-called functional demographic model (FDM). They propose a methodology to forecast age-specific mortality rates, based on the combination of functional data analysis, non-parametric smoothing and robust statistics. In particular, the approach under consideration, allows for smooth functions of age, is robust to outliers and provides a modeling framework easy to fit to constraints and other information.

Let $y_t(x)$ denote the log of the observed mortality rate for age x and year t, $f_t(x)$ the underlying smooth function, $\{x_i, y_t(x_i)\}$, $t = 1,...,n$, $i = 1,...,p$ is the functional time series, where:

$$y_t(x_i) = f_t(x_i) + \sigma_t(x_i)\varepsilon_{t,i}, \tag{8}$$

with $\varepsilon_{t,i}$ an i.i.d. standard normal random variable and the $\sigma_t(x_i)$ allows for the amount of noise to vary with x. The steps for forecasting $y_t(x)$ are summarized as follows:

1. The dataset is smoothed for each t by applying penalized regression splines. Using a non-parametric smoothing with constraint, we estimate for each t the functions $f_t(x)$ for $x \in [x_1, x_p]$ from $\{x_i, y_t(x_i)\}$ for $i = 1,..., p$. We assume that $f_t(x)$ is monotonically increasing for $x > c$ for some c, that is reasonable for mortality data. This constraint allow to reduce the noise in the estimated curves at older ages.

2. The fitted curves are decomposed by using a basis function expansion:

$$f_t(x) = \mu(x) + \sum_{k=1}^{K} \beta_{t,k}\varphi_k(x) + e_t(x), \tag{9}$$

where $\mu(x)$ is a measure of location of $f_t(x)$, $\varphi_k(x)$ is a set of orthonormal basis functions and $e_t(x) \sim N(0, v(x))$.

3. To each coefficients $\{\beta_{t,k}\}$, $k = 1,..., K$, univariate time series models are fitted.

4. On the basis of the fitted time series models the coefficients $\{\beta_{t,k}\}$, $k = 1,..., K$, are forecasted for $t = n + 1,..., n + h$.

5. The coefficients obtained in the previous step are implemented to get the $f_t(x)$ as in equation (9). From (8) the $y_t(x)$ are projected.

6. Finally, in order to determine confidence intervals for mortality projections, the variance of error terms is calculated.

3. The impact of longevity on transformation coefficient

Longevity reflects improvements in mortality trend and determines systematic deviations of the number of the deaths from its expected values. In Italy this process developed during the 20th century, due to progress in medicine and in general economic and social conditions. Figures 1 and 2 show the general drop in the Italian male mortality rates during the period of 1965-2005. Improvements in mortality are not uniform across the ages and the years: first of all, reductions in mortality rate are stronger for ages between 0 and 10. As it is clear, there is an increasing variance for higher ages, especially around $x = 100$. In the case of older ages, the high variability can be due to small exposures to risk and this is a common problems when estimating mortality rates for groups aged 100 and more.
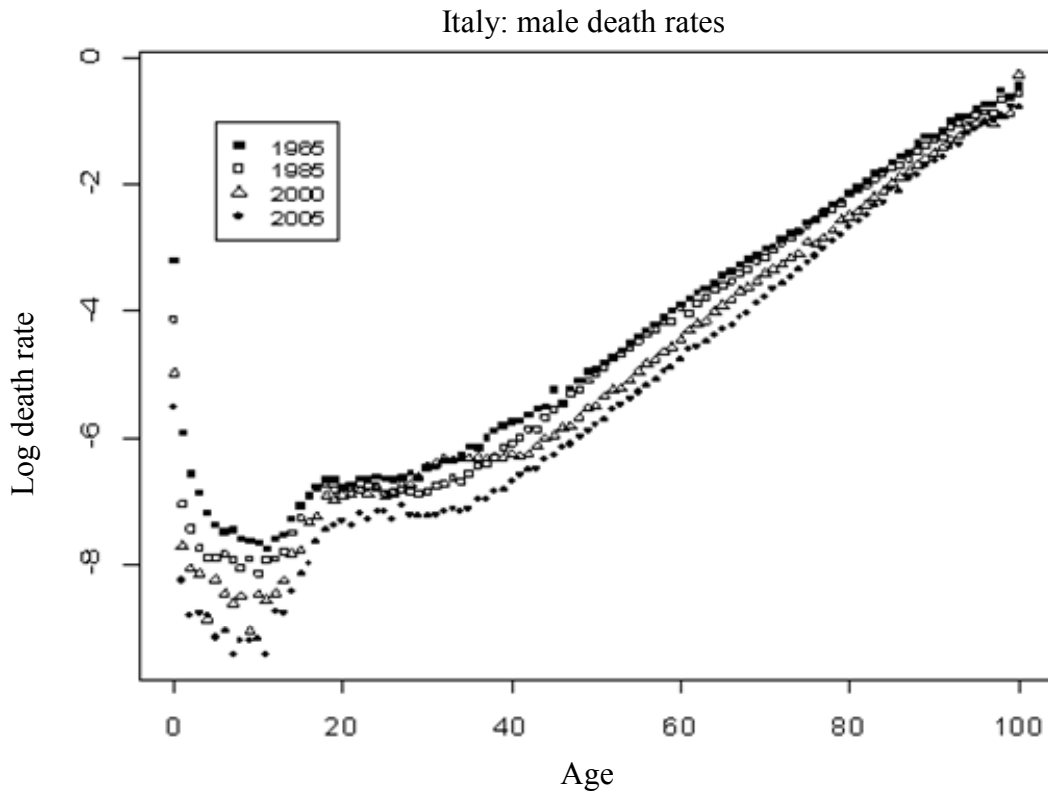
Italy: male death rates

Fig. 1. Italian male death rates, 1965-1985-2000-2005
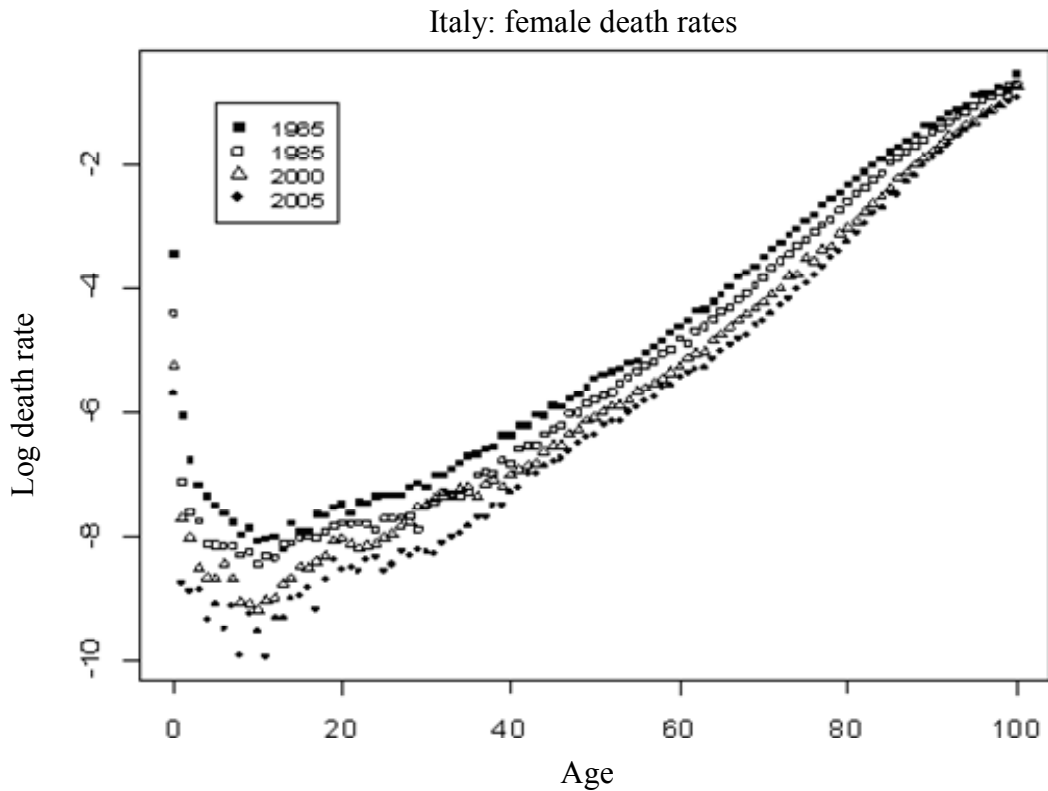
Italy: female death rates

Fig. 2. Italian female death rates, 1965-1985-2000-2005

In order to fit the Lee Carter model to Italian data, we have considered the annual Italian male and female mortality rates from 1965 to 2006 for single year of age (the data are downloaded from the hu-man mortality database). To avoid the problem of high variability at older ages, we have considered as final age 100. Figures 3 and 4 show the fitted parameters for male and female population.
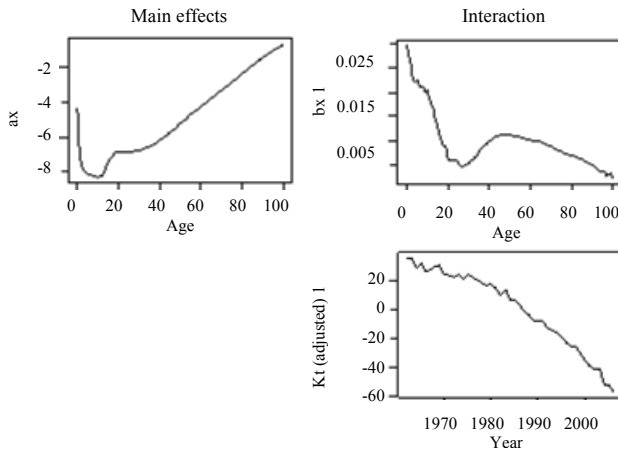
Fig. 3. The parameter estimates of basic Lee Carter model on Italian male mortality data
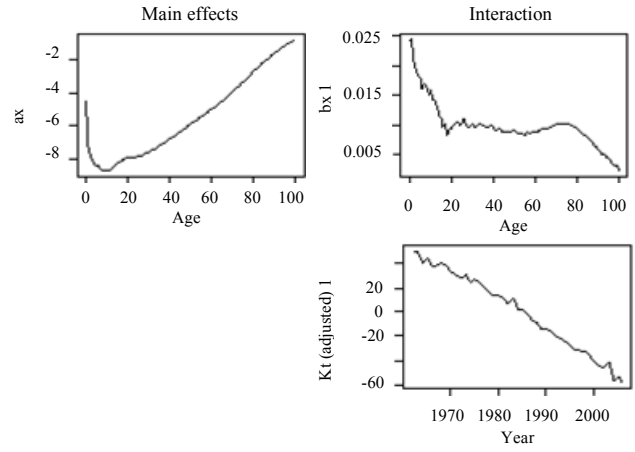

Fig. 4. The parameter estimates of basic Lee Carter model on Italian female mortality data

The resulting estimate of the time-varying parameter is then modeled as a stochastic process through Box-Jenkins techniques and forecasted for the years 2007-2050. The forecasted k_t are used to produce forecasted mortality rates. Finally, mortality rates permit to construct the projected mortality table, which includes the projected numbers of survivors at each future year. At this point, we apply equations (4)-(6) and derive the estimations of transformation coefficients for 2013. We set $g_f = 0.015$, $\theta = 0.6$, $\gamma = 0.42$, $r = 0.015$ according to the Law 335/95. Results are summarized in Table 2; a comparison with the coefficients established by the Laws 335/95 and 247/07 is offered in Figure 5.

Table 2. Projected transformation coefficients applying Lee Carter model

Retirement age	57	58	59	60	61	62	63	64	65
Transf. coeff.	4.278%	4.344%	4.410%	4.478%	4.547%	4.617%	4.687%	4.759%	4.832%
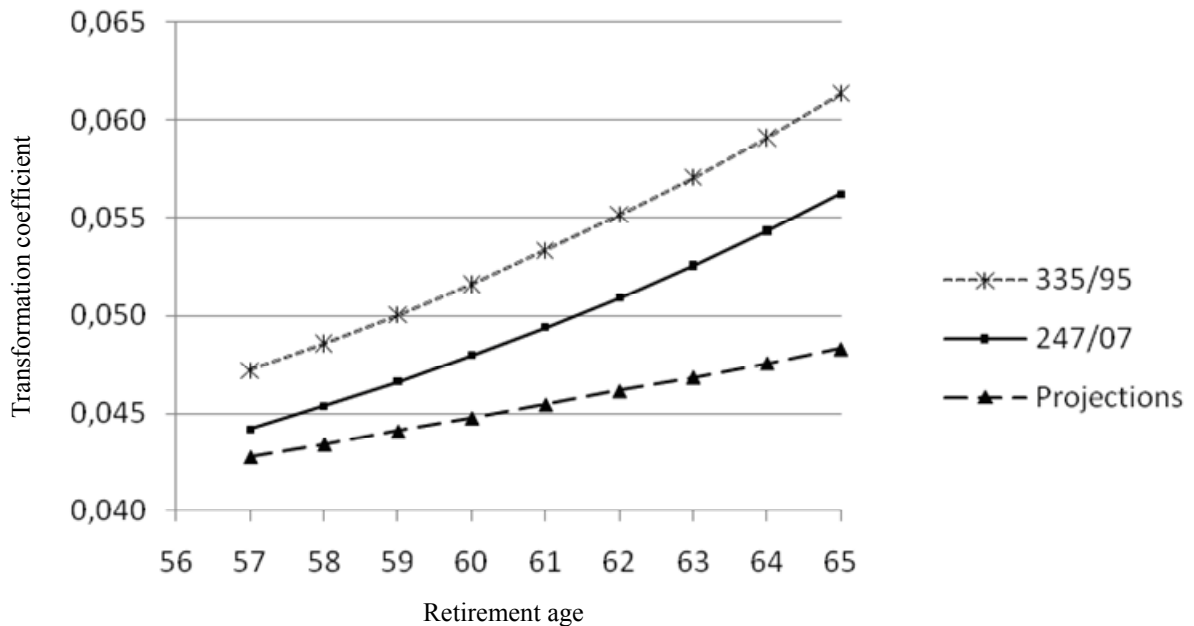
Fig. 5. A comparison between the transformation coefficients

The transformation coefficients calculated applying the Lee Carter model incorporate improvements in life expectancy. They are lower than those fixed by laws 335/95 and 247/07; consequently, an increase in life expectancy entail a reduction in the transformation coefficient. This is due to the principle of actuarial fairness, according which the worker, who lives longer, receives a smaller monthly pension but for a longer period. In particular, the reduction in the transformation coefficients is greater as the retirement age increases. The last step of our analysis consists into produce other projections fitting the FDM on the Italian male and female mortality rates from 1965 to 2006 and forecasting mortality rates for the period of 2007-2050. Figures 6 and 7 show the fitted parameters for male and female.
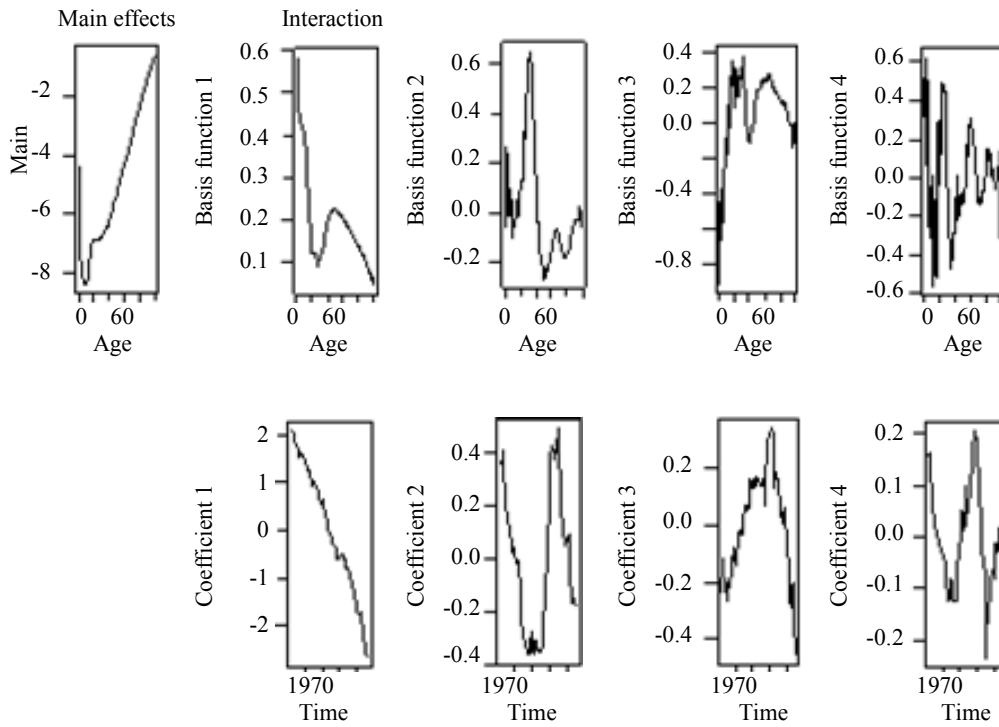
Fig. 6. Basis functions of FDM and associated coefficients for Italian male population
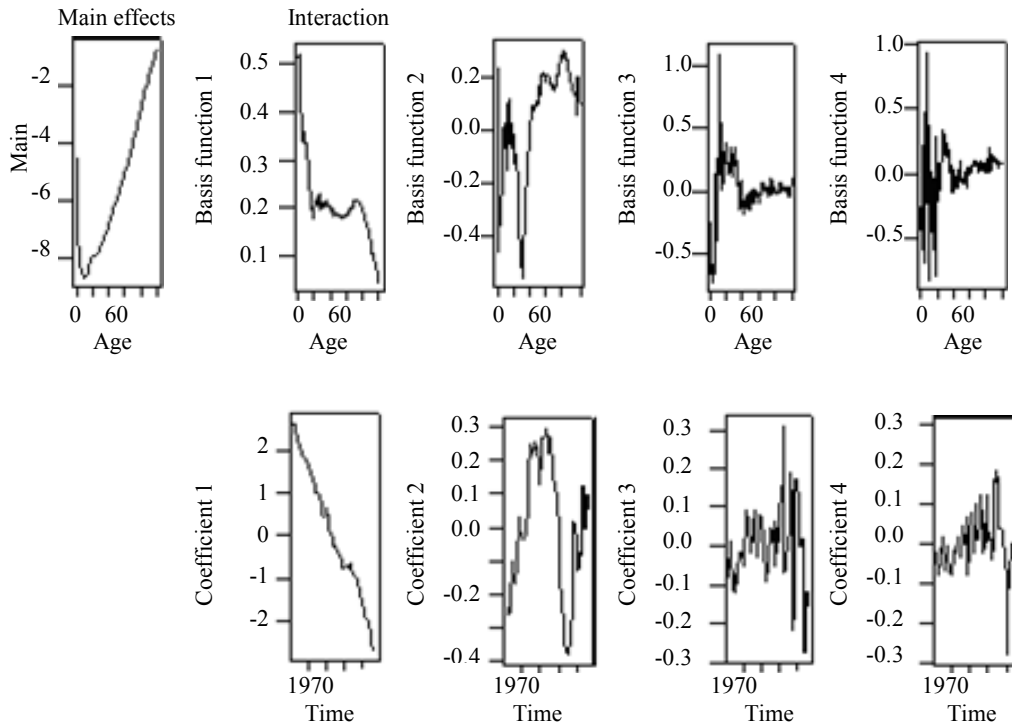

Fig. 7. Basis functions of FDM and associated coefficients for Italian female population

Likewise we have done previously, we derive the estimations of transformation coefficients for 2013. The transformation coefficients calculated using mortality probabilities projected applying the functional demographic model are presented in Table 3.

Table 3. Central projections of the transformation coefficients

Model	Retirement age								
	57	58	59	60	61	62	63	64	65
FDM	4.25%	4.31%	4.38%	4.45%	4.52%	4.59%	4.66%	4.73%	4.80%
Lee Carter	4.278%	4.344%	4.410%	4.478%	4.547%	4.617%	4.687%	4.759%	4.832%

The reduction in the transformation coefficient is more severe if mortality projections are conducted through the FDM than the Lee Carter. D'Amato et al. (2009) show for Italian data that the forecast accuracy is higher for the FDM than for the Lee Carter.

Finally, we highlight that a further reduction in the projection of transformation coefficient is expected, because in the application we have considered as final age 100, disregarding the older age. On the contrary, we have not considered the probability for the widow(er) to marry again and the reduction in the widow(er)'s pension due to her (his) additional income. These issues can be faced in further works.

Concluding remarks

In 1995 in Italy was introduced notional defined contributions system in the pay-as-you-go pension pillar. According to this scheme, contributions paid during the working life are accumulated at the expected economic growth rate until the retirement age, when the amount is converted into a life annuity taking into account the forecasted expectancy of life. In order to ensure actuarial fairness reasonable mortality forecasts have to be considered. Longevity risk, due to systematic deviations of the number of the deaths from its expected values, impacts on pension providers or workers depending on when it take place.

If life-expectancy improvements occur during the working life, the risk is born by workers. In fact, government will set a smaller rate at which the accumulated balances are converted into pension benefit taking into account the longer life-expectancy. This is a pre-retirement risk. If the projections of life expectancy are estimated with a high degree of certainty, workers can plan the retirement age according their consumption needs. Instead, if life-expectancy raises more than expected, retirees will obtain lower pension benefits and have to adapt their lifestyle. Bianchi et al. (2003) analyze individual behavioral responses to the constraints generated by social security system.

The post-retirement risk, i.e., the risk that life-expectancy improvements occur during the retirement, is born by pension provider. Such trends in mortality reduction present risk for annuity provider which have planned on the basis of historical mortality tables the pension benefits they have to paid.

In this paper we have analyzed the current reform of the Italian public pension system and studied the impact of longevity risk on transformation coefficients, which are applied to accumulated balances in order to convert them into pension benefits. From a theoretical point of view, the actual pension scheme obey the principle of actuarial fairness; from a practical one, the fairness is hindered by redistribution between genders. In fact, the same rules are applied to calculate transformation coefficient for male and female pensioner; so females receive, ceteris paribus, the same pension of males but the formers have a longer life-expectancy. Another aspect that invalidates the fairness is the discontinuity in the process reform: transformation coefficients need to be regularly adjusted in order to capture the evolution of expectancy of life. We have quantified the impact of longevity risk on transformation coefficients for 2013 using a mortality table projected with two different stochastic model, the widely used Lee Carter model and its extension functional demographic model. The results obtained can be considered a reference frame for workers, who are scheduling retirement for the years, and government, who is engaged in the next coefficient revision.

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