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Original Article

Mortality dynamics and the statutory retirement age proposal: an actuarial view

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ABSTRACT

This paper aimed to apply (dynamic and static) actuarial models to calculate the balanced contribution rates for the planned (at the minimum age) retirement benefit of the General Social Security System, based on the original and substitutive texts of the reform proposed by Michel Temer's government. Even with the regular increases in life expectancy and the long-term nature of the analyses, national studies on social security are typically based on the static mortality hypothesis. The relevance of this study is evident due to the demographic changes, particularly the increase in life expectancy, experienced by the Brazilian population in recent decades and which put in question the sustainability of the national pension system. The use of dynamic actuarial models allows for more accurate discussions about the future of social security, besides contributing to the still scarce national literature. Static and dynamic actuarial models were applied to a representative individual, adjusting mortality tables from the United Nations covering 1950 to 2100. It was verified that the actuarially fair rates calculated by the dynamic actuarial model are typically higher than those obtained by the static model, especially for women. This difference is expected to increase as gains in life expectancy become more influenced by the reduction in mortality at more advanced ages. Moreover, if the social security reform is approved (in accordance with either the original or the substitutive text), there are indications from the dynamic model that the contributions rates currently charged would be excessive for men. In turn, these rates would be excessive for women considering the original text, and closer to the actuarially fair value considering the substitutive text. The development, disclosure, and regular updating of official dynamic tables (whether for mortality or other biometric assumptions) are also recommended.

Keywords: RGPS, pension reform, life expectancy, mortality table, retirement.

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1. INTRODUCTION

With a clear fiscal motivation that involves reducing public spending on pensions (Afonso, 2018), in December of 2016, Proposed Constitutional Amendment n. 287-A of 2016 (or PEC n. 287-A, as abbreviated in Portuguese) was launched. This proposal aims to promote reform of the national social security system, including both the General Social Security System (RPGS in Portuguese) and the Special Social Security System (RPPS in Portuguese), seeking greater equality in the rules for both systems, a revision of the eligibility criteria for retirement, the adoption of a (progressive) minimum retirement age, and a revision of the rules for calculating the value of retirement and pension benefits, among other aspects.

One of the main arguments in favor of the reform is linked to the demographic changes that have occurred in the country in recent decades, in particular with the reduction in birthrates and regular increases in life expectancy, seriously affecting the system's sustainability (Lima & Matias-Pereira, 2014). To understand the potential impacts of the reform proposal, actuarial studies have been conducted both for the RGPS and the RPPS.

However, despite seeking to discuss peculiarities of the reform, such as the mortality heterogeneity of the Brazilian population (Souza, 2018), balanced contribution rates based on applying multidecremental models (Gouveia, Souza & Rêgo, 2018), the comparison of social security indicators (Afonso & Zylberstajn, 2017), and specific discussions about the RPPS (Dias, 2018), these studies present the methodological limitation of using period mortality tables, which only consider the mortality observed in a given time period (Ortega, 1982) in their analyses, even when faced with scenarios of increasing life expectancy. Indeed, research based on period tables ignores the dynamic behavior of mortality.

This study aimed to apply dynamic actuarial models, which make use of tables built based on past observations regarding mortality, but also enable future mortality projections (Pitacco, Denuit, Haberman & Olivieri, 2009), in the discussion process concerning the proposed social security reform, in particular in the RGPS, due to its coverage and economic importance, thus bringing the discussion closer to the literature and international practices (Pitacco et al., 2009).

Therefore, this article's central objective is to calculate for the RGPS, based on dynamic and static actuarial models (for the years from 1997 to 2037, in 10-year intervals), the actuarially fair (or balanced) contribution rates for the planned (at the minimum age) retirement benefit, separated by sex, based on the original text of the reform (PEC n. 287-A) and the substitutive text (Global Agglutinating Amendment to Proposed Constitutional Amendment n. 287-A, of 2017). Thus, this study enables: (i) a comparison of the contribution rates before the two reform proposal scenarios; (ii) a comparison of the results in static and dynamic mortality scenarios; (iii) a discussion of the results for the male and female sexes; and (iv) the variations and tendencies of the rates to be monitored over time. In addition, besides the results, this research contributes to strengthening the still scarce national literature on the adoption of dynamic actuarial models in the social security discussions, thus also encouraging new research.

Martins and Campani (2019) stress that the current discussions about social security reform in Brazil can generally be put into three categories (even though some studies maintain an intersection between two or more areas): those that address fiscal sustainability, those that discuss distributive progressiveness, and those that focus on the beneficiary/taxpayer. In this spirit, by analyzing the actuarially balanced contribution rates (that is, that equate the expected flow of benefits to the expected flow of contributions), this article fits mainly into the third group and helps in the discussions about the attractiveness and actuarial fairness of the national social security system. However, it is understood that the results shown here have the potential to contribute for those interested in the debate about distributivity and technical/actuarial aspects linked to fiscal sustainability.

Regarding the period chosen (from 1997 to 2037), this is due to the availability of information and enables a longitudinal view of the changes in mortality, analyzing how the contribution rates should be if the minimum retirement age (in the proposed molds) had already been implemented by Fernando Henrique Cardoso's government or were postponed to future generations. On this point, it is worth highlighting that, in the hypothetical exercise developed here, transition rules were not considered. Finally, the process for calculating the rates used the representative individual approach and the definition of assumptions aligned with the literature.

To achieve the objective outlined, the rest of the paper is organized as follows: section 2 presents the study's theoretical framework, with explanations regarding the use of static and dynamic mortality tables and about the proposed social security reform, focusing on the RGPS and the adoption of a minimum retirement age.

Section 3 describes the processes for the collection and adjustments of the mortality tables and the construction of the dynamic table, as well as explaining the models and actuarial assumptions applied. Section 4 presents the main results of the study and discusses them in light of the literature, as well as carrying out the sensitivity analysis of the parameters. Finally, section 5 summarizes the conclusions, highlights the limitations of the study, and suggests future investigations in order to complement the subject under debate.

2. THEORETICAL FRAMEWORK

2.1 Mortality: Static and Dynamic Aspects

Tendencies in the behavior of human mortality and mortality projections only started being monitored with scientific rigor when mortality tables began to be developed and updated over time. According to Pitacco (2004), in a historical context, the pioneering studies in this area occurred in Sweden, at the end of the 19th century, based on the recording and analysis of the mortality rates of the Swedish population between 1750 and 1870. Currently, studies on human mortality projections form a vibrant area of actuarial science due to their relevance in medium and long term planning.

According to Pitacco et al. (2009), in general, a mortality table is a finite table that expresses, for a sequence of whole and non-negative ages, the number of survivors (and dead) at these ages. The l_x symbol indicates the number of people alive at age x based on an initial group of individuals [typically from age zero (l_0)] and, as it is finite, there is a limiting age (ω), such that $l_{\omega-1}>0$ and $l_\omega=0$.

Also according to the authors, if the values l_0, l_1, ..., $l_{\omega-1}$ are calculated based on statistical observations regarding the frequency of deaths at each age and based on information from a given period (for example, a given calendar year t), this sequence is called a period mortality table. If, in turn, the values are derived from a longitudinal observation (over ω years) of the decremental behavior of a real group of newborns (born in calendar year t', for example), this sequence is called a cohort mortality table. Thus, a period mortality table is based on a fictitious cohort and admits the static mortality hypothesis, that is, that there is no alteration in the future behavior of mortality.

Taking a period mortality table built with observations from year t (fixed), $p_x(t)$ is defined as the probablity of a person of age x surviving up to at least age x+1. In addition, if ${}_np_x^{\uparrow}(t) = \prod_{j=0}^{n-1} p_{x+j}(t)$ is the probablity that a life aged x survives to at least age $x+n$, and assuming a uniform distribution of deaths over the year, the complete period life expectancy at age x, $e_x^{\uparrow}(t)$, is defined as:

$$e_x^{\uparrow}(t) = 0.5 + \sum_{n=1}^{\omega-x-1} {}_np_x^{\uparrow}(t) \qquad (1)$$

Period life expectancy at birth is one of the main health indicators of a population at a particular moment in time, and recording it serves to monitor improvements in the health and quality of life conditions of a population over time and/or enable comparisons between different locations at the same time. In recent decades, successive increases in life expectancy have become a global trend, even in Brazil (Brazilian Institute of Geography and Statistics – IBGE, 2013b), with some specific exceptions, as can be seen in Souza and Rêgo (2018).

Just as Pitacco et al. (2009) highlight, this trend of a reduction in mortality levels means the static mortality hypothesis is not appropriate for long term analyses – as is the case of actuarial studies regarding social security. This type of research would require projected (or dynamic) mortality tables, that is, built based on past observations regarding mortality, but that also enable future mortality projections. Thus, mortality would become a function of age x and calendar year t, which would cease to be fixed.

Formally, based on Pitacco et al. (2009), a projected mortality table can be defined by $\{p_x(t)\}_{x\in X; t\geq t'}$, in which X is a set of ages and t' is the base calendar year. So, a projected mortality table is a matrix that, for a succession of (whole) calendar years starting in t', expresses the probabilities of survival, in each year, for a succession of whole and non-negative ages. Thus, ${}_np_x^{\nearrow}(t)$ expresses the probability that a life aged in year survives to at least age $x+n$ in year $t+n$ and is formally represented by:

$${}_np_x^{\nearrow}(t) = \prod_{j=0}^{n-1} p_{x+j}(t+j) \qquad (2)$$

According to Pitacco (2004), the elements of the matrix $\{p_x(t)\}_{x\in X; t\geq t'}$ can be analyzed under three perspectives: (i) first, there is the vertical (or column) view, in which the values $p_0(t)$, $p_1(t)$, ..., $p_x(t)$, ..., $p_{\omega-1}(t)$ refer to a period mortality table for calendar year t (fixed); (ii) second, there is the diagonal view in which the values $p_0(t)$, $p_1(t+1)$, ..., $p_x(t+x)$, ..., $p_{\omega-1}(t+\omega-1)$ refer to a mortality table of a cohort born in year and are used in the dynamic analysis of mortality; (iii) and finally, there is the horizontal (or by line) view in which the values ..., $p_x(t-1)$, $p_x(t)$, $p_x(t+1)$, ... indicate the evolution of the probability of survival at age x with the passing of time.

In this dynamic context (diagonal view), also assuming a uniform distribution of deaths over the year, the cohort life expectancy is defined as:

$$e_x^{\nearrow}(t) = 0.5 + \sum_{n=1}^{\omega-x-1} {}_np_x^{\nearrow}(t) \qquad (3)$$

At this point, it is worth highlighting that the symbols adopted in this article follows that of Pitacco et al. (2009) and the arrows (vertical and diagonal) used as accessory symbols in the notations convey the idea of how the displacement occurs throughout the tables (vertical and diagonal views, respectively). In addition, due to the improvements in health conditions, for the whole calendar year t and for a given age x, with $0 \leq x < \omega - 1$ we typically have $p_x(t) < p_x(t+1)$ and, for simplicity, it is also assumed that for the whole of t, $p_{\omega-1}(t)=0$ (Cossete, Delward, Denuit, Guillot & Marceau, 2007).

Based on the data from the United Nations (2017), Figure 1 presents the comparison between the period and cohort life expectancies at age 65 years-old for Brazil (both sexes), between the years 1997 and 2047. From the figure it can clearly be seen that the cohort life expectancy is always higher than the period life expectancy. In addition, this difference is expected to be 1.2 years between 2017 and 2047, on average.

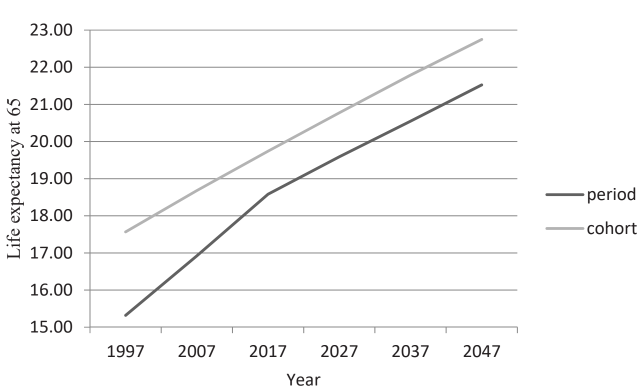

Figure 1 *Comparison of the period and cohort life expectancies at age 65 years-old, for both sexes, between 1997 and 2047.*
Source: *Elaborated by the author based on data from the United Nations (2017).*

Guerra and Fígoli (2013) highlight that period life expectancy is a lagged indicator of the real life expectancy of a cohort. Thus, in the example shown in Figure 1, as $e_{65}^{\nearrow}(2017)=19.74$, it is perceived that this threshold would only be obtained in a period mortality table more than 10 years later, since $e_{65}^{\uparrow}(2017)=18.58$, $e_{65}^{\uparrow}(2027)=19.59$, and $e_{65}^{\uparrow}(2037)=20.55$.

Queiroz and Sawyer (2012) emphasize that knowing the mortality profile of the Brazilian population and understanding the demographic changes that the country has undergone would enable a conscience direction for fiscal planning, social policies, the provision of services, and therefore, the size of public spending, with a direct effect on the areas of health, education, and social security, among others.

2.2 Minimum Retirement Age and the Proposed Social Security Reform

In the recent history of reforms in Brazilian social security, beginning in Fernando Henrique Cardoso's government and continued in Luiz Inácio Lula da Silva's and Dilma Rousseff's governments, the proposal presented by Michel Temer's government, through PEC n. 287/2016, is, according to Afonso and Zylberstajn (2017) and Afonso (2018), considered to be the greatest attempt to overhaul the Brazilian social security system, even though it is a parametric reform. According to the authors, the reform under discussion has a clear fiscal motivation, especially after the enactment of Constitutional Amendment n. 95/2016, which limits public spending for 20 years and has been justified by the demographic changes occurring in the country in recent decades.

Carvalho and Garcia (2003) indicate that the reduction in the birthrate has affected the structure of the Brazilian age pyramid, resulting in an ageing population, accelerated due to the process of increasing life expectancy. The authors also indicated that these increases should change the understanding of what an elderly person is (which, in general, is taken to be an individual who is 60 years old or more).

These two demographic tendencies have direct impacts on the funding of the national social security system by reducing the proportion of active workers per beneficiary and increasing the expected time to receive retirement benefits. Souza, Queiroz, and Skirbekk (2018) argue that due to improvements in health conditions in recent decades there is potential for an increase in retirement ages in Brazil and in other countries in Latin

America, which would be emphasized by the reduction in the physical demands placed on workers, enabling greater professional longevity. In addition, the authors also highlight that over the years, even with successive increases in life expectancy, there has been a reduction in the share of elderly people in the labor market, which goes against what would be expected.

So, in light of these arguments, one of the main strategies foreseen in the current reform proposal for Brazilian pensions is to link the defined (progressive) minimum age for retirement to (period) life expectancy at 65 for both sexes. Thus, whenever this life expectancy increases by a year, based on life expectancy on the date that PEC n. 287/2016 was announced, the minimum age for retirement would also increase by one year. Initially, in the original text of the reform (PEC n. 287-A), the minimum age foreseen would be 65 for both men and women, but this was revised to 62 for women in the substitutive text of the reform (Global Agglutinating Amendment to PEC n. 287-A). A summary of the minimum age, time of contribution, and retirement benefit calculation rules, both for the original PEC n. 287-A and for its substitutive text, is seen in Table 1. This summary is inspired by Dias (2018), who carried out a similar analysis for the RPPS.

Lourenço, Lacaz, and Goulart (2017) indicate that attempts to define the minimum age for retirement are not new in Brazil. Fernando Henrique Cardoso's government sought, without success, to define such a reform strategy (65 years old for men and 60 for women), which was ultimately substituted by the social security factor – which also takes into consideration (period) life expectancy at the time of retirement.

The discussion regarding pension reform and the adoption of a minimum retirement age is not particular to Brazil. According to the Organization for Economic Cooperation and Development (OECD), almost all its member countries have or aim to have a normal retirement age of 65 years-old for men and women (OECD, 2013). In addition, according to the OECD (2017), countries such as Denmark, Finland, Italy, the Netherlands, Portugal, and Slovakia also aim to align the alterations in the normal retirement age with improvements in the life expectancy of their populations.

Table 1

Summary of the proposed reforms regarding the minimum age and benefits calculation for retirement for the General Social Security System (RGPS)

Aspect	PEC n. 287-A/2016 (original text)	PEC n. 287-A/2017 (substitutive text)
Minimum age	65 for men and women	65 for men and 62 for women
Minimum contribution time	25 years	15 years
Retirement benefit*	51% + 1% per year of contribution of the mean of the contribution salaries, respecting the maximum limit of 100% of the mean	60% + 1% of the 1st to the 10th group of 12 contributions that exceeded the minimum contribution time + 1.5% of the 11th to the 15th group of 12 contributions that exceeded the minimum contribution time + 2% of the 16th to the 20th group of 12 contributions that exceeded the minimum contribution time + 2.5% from the 21st group onwards of 12 contributions that exceeded the minimum contribution time of the mean of the contribution salaries respecting the maximum limit of 100% of the mean.

** respecting the pension limits (ceiling and floor).*

***Source**: Adapted from Dias (2018), based on Proposed Constitutional Amendment n. 287-A of 2016 and the Global Agglutinating Amendment to Proposed Constitutional Amendment n. 287-A of 2017.*

These measures, which seek to define legal mechanisms to be applied in the case of an alteration in predetermined solvency and/or demographic indicators (as in the case of life expectancy), are known in the actuarial literature as automatic adjustment (or balancing) mechanisms (Vidal-Meliá, Boado-Penas & Settergren, 2009). The adoption of these mechanisms has been globally accepted since, according to the authors, they reduce political pressure and electioneering use of the social security system, they enable immediate action when a deviation is detected, and they provide the system with greater credibility and transparency.

Even with favorable arguments, such a deep reform is not presented without undergoing heavy criticisms. For Lourenço et al. (2017), the argumentation that there is a pension system shortfall is due to the lack of contributions from the State as an employing entity, evasion and fraud, and tax exemptions given by the government. Added to this is the question that state pensions form part of Social Security and, therefore, should be funded with resources from this, and not only with pension contributions. Finally, for the authors, the fact that Social Security resources are diverted for other purposes, when there is talk of a pensions deficit, is a contradiction. Silva, Puty, Silva, Carvalho, and Frânces (2017) complement this argumentation by emphasizing that the predictions made by the government in support of the pro-reform arguments have questionable reliability, since they involve little transparency of the methods used, making replicability of the results difficult. The authors also emphasize that the projections are biased towards the short term (overestimating the deficit, for example) and, indeed, would have little utility in long term analyses. Souza (2018) also indicates that defining a high minimum retirement age could affect workers in professions with greater physical demands and who may be interested in retiring at younger ages, even with salary losses, as well as the fact that it could cause negative redistributive effects for the system.

In contrast, defenders argue that, independently of there being a pensions deficit (or not), it is notable that pensions spending has increased and that Brazil, a country with a relatively young population when compared with other countries in Europe, for example, already spends the same amount on pensions as a percentage of gross domestic product (GDP) as longer-living countries, which would aggravate the situation in the long term. High pensions spending would imply that the funds invested in pensions are not applied in other areas of public interest (Afonso and Zylberstajn, 2017). In addition, Costanzi and Ansiliero (2016) indicate that contribution time retirement (without a minimum age requirement) benefits workers with higher income and education levels in more stable professions, while poorer workers end up retiring due to age and via continued payment benefit.

Another point to be highlighted regarding pension reform is that this has stimulated an important academic discussion, especially with regards to its potential impacts, evaluated based on actuarial studies, such as Afonso and Zylberstajn (2017), Dias (2018), Gouveia et al. (2018), and Souza (2018). Besides the subject, these studies have in common the fact that in their analyses they consider the use of period (static) mortality tables, which from a long-term perspective, as in the case of retirement flows, means that despite their relevance the results need to be interpreted with caution. Indeed, since the reform and adoption of a minimum age are warranted in part due to the increases in life expectancy of the Brazilian population, nothing could be more natural than analyzing potential impacts of the reform using actuarial models that consider this dynamic aspect of mortality. It is precisely into this gap in the national literature than this article fits.

In the literature on the national social security system, the work of Zarzin, Wajnman, and Turra (2012) stands out, who examined the income distribution between racial groups in Brazil caused by state pensions. In this study the authors used both the life cycle approach (which uses a dynamic actuarial model) and a period analysis, and found that the pension rules in effect at the time, by protecting the poorest, played a role in reducing the income inequality between elderly black and white people.

In the literature and international public practices, aspects linked to the dynamics of mortality have been a current issue, especially in discussions about the long-term sustainability of fiscal policies and reforms to pension systems. Lee and Tuljapurkar (1997) highlight that, in these discussions, previously dominated by changes in birthrates, the influence of the constant reductions in mortality levels has assumed an important role. For Andersen (2012), in the pensions context, the increase in the dependency rate driven by a higher life expectancy (unlike that driven by a lower birthrate) suggests the need for measures to increase the legal retirement ages.

As an example of the application of dynamic actuarial models in discussions regarding actuarial fairness, there is the paper from Belloni and Maccheroni (2013), which analyzes actuarial characteristics of the Italian pension system during the transition from a defined benefits system to a notional defined contribution one. As a result, it was found that due to the recent reforms the Italian system could go from generous (in which retirees receive greater benefits than the actuarially fair) to a more austere system, in which there are indications that the value of the benefits would be lower than the fair value. The authors also suggest that mortality projections be applied (and regularly updated) to guarantee that the system is more appropriate.

Another interesting study is that of Heiland and Yin (2014). According to the authors, the U.S. pension system establishes measures for actuarial adjustment of the retirement benefits of those who choose both early and postponed retirement. And since the introduction of the early retirement option, at the end of the 1950s and start of the 1960s, the structure of these measures has undergone a series of alterations. The authors investigated whether this agenda of adjustments is actuarially fair, particularly in light of the tendency for growth in cohort life expectancy. The study found that the adjustment mechanisms have improved over the generations, getting ever closer to the fair value, and that the increases in the full retirement age that accompany the increases in life expectancy have contributed to this.

3. METHODOLOGY

3.1 Data on Mortalilty

In order to use dynamic actuarial models, long records and projections of mortality need to be available. IBGE (2013a) provides this type of data, but only with projections up to 2060, which is insufficient to carry out the analysis in question. Thus, it was decided to use the already existing data referenced in the literature (Amaro & Afonso, 2018; Souza et al., 2018) and, therefore, the information on mortality was obtained from the United Nations Population Division database (United Nations, 2017).

This database provides static and abbreviated mortality tables (with information for ages 0, 1, 5, 10, 15, ..., 80, and 85 or more) relating to five-year periods from 1950-1955 up to 2095-2100 and segregated by sex (both sexes, male and female). These tables were used to build the complete mortality tables and the dynamic model.

Initially, for every five-year interval, it was considered that it would be closed at the lower limit and open at the upper limit, that is, for 1950-1955, the interval considered was [1950, 1955) and, for the next five-year interval, it was [1955, 1960), following this same idea up to [2095, 2100). Subsequently, the central points of the respective intervals were considered to be the calendar year of each one of the five-year static tables; so, for example, 1952 would be used for the 1950-1955 table and so on up to 2097, representing the mortality profile of the 2095-2100 table, totaling 30 abbreviated mortality tables for each category (both sexes, male and female).

Then, it was necessary to expand these abbreviated mortality tables to complete ones. Consistently with the practices adopted by official bodies (IBGE 2016; Silva, 2015), this procedure was divided into three parts: for ages from 1 to 4, a hyperbolic adjustment of the number of survivors was carried out and, for ages from 5 to 85, it was assumed that the survival function followed a Gompertz curve as defined by the IBGE (2016) and discussed in Souza (2018). For the ages above 85, the approach was based on the methodology developed by Silva (2015) and adopted for extrapolation of the IBGE mortality tables. This last stage consists of defining (for each calendar year) adjustment factors (*AF*) that would enable the calculation of the number of survivors between 86 and 115 years old, so that the module of the difference between the life expectancy at 85 obtained from the complete table and the expectancy indicated in the abbreviated table is lower than 0.01 year. Thus, according to Silva (2015), for a given calendar year, the number of survivors for ages above 85 would be defined as:

$$l_{x+2} = l_{x+1}\left(\frac{l_{x+1}}{l_x + AF}\right) \tag{4}$$

Having obtained the complete tables for the years 1952, 1957, …, 2097, the tables for the intermediate periods were obtained using the process of linear interpolation of the survival rates, totaling 146 complete mortality tables for each stratum. In addition, taking/pairing the survival rates for each age in each calendar year, the dynamic mortality table was built, taking 1952 as the base year.

3.2 Actuarial Models and Assumptions

The balanced contribution rates calculation is based on the principle that the expected present value of the social security contributions (*EPVC*) made in favor of the employee should be equal to the expected present value of the pension benefits (*EPVB*) due to them, which in the case being analyzed correspond to the planned retirement benefits based on the minimum retirement age. Initially, the development of the model will be divided into two parts, the first referring to the original text of the PEC n. 287-A (highlighted by the letter *o*) and the second referring to the substitutive text (highlighted by the letters *s,m*, for men and *s,w* for women).

For all the cases under analysis, it is assumed that there is a real discount rate of *i*% per year (p.a.), where $i = 3\%$ p.a. (Gouveia et al., 2018; Souza, 2018), that the employee joins the labor market at 20 years-old receiving an annual salary equal to S_{20}, which grows at a real rate of i_s% p.a., where $i_s = 2\%$ p.a. (Gouveia et al., 2018; Souza, 2018), and that over their active lifetime, all the employee's salaries are at the RGPS pension limits (ceiling and floor). In addition, for simplicity it is assumed that the financial flows are in advance and annual in periodicity and that there is a

100% contribution density. Finally, the retirement benefits received based on the minimum age r (B_r) have null real growth.

As seen in Table 1, considering the original text of the reform, the minimum retirement age for both sexes would be 65, with a minimum period of 25 years of contributions. In addition, if TC is the time of contribution (measured in years), the retirement benefit at 65 would be equivalent to 51 + TC% of the mean of the contribution salaries, respecting the ceiling of 100% of the mean and the pension limits. Thus, as it is assumed that the worker starts their active life at 20, this would correspond to 96% of that mean. So, from the above, and if c^o is the balanced contribution rate given the original text of the reform, in a dynamic actuarial context, $EPVC^o$, $EPVB^o$, and B_{65}^o can be defined both for women and for men, for an individual who retires at 65 in calendar year t, as being:

$$EPVC^o = \sum_{n=0}^{44} c^o . S_{20} . \frac{(1+i_s)^n}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-45) \quad \boxed{5}$$

$$EPVB^o = \sum_{n=45}^{\omega-21} B_{65}^o . \frac{1}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-45) \quad \boxed{6}$$

$$B_{65}^o = 0.96 . \frac{S_{20}}{45} . \frac{(1+i_s)^{45}-1}{i_s} \quad \boxed{7}$$

Substituting the value of B_{65}^o in equation 6 for the right side of equation 7, and equaling this result to equation 5, the balanced contribution rate is obtained:

$$c^o = \frac{\sum_{n=45}^{\omega-21} 0.96 . \frac{(1+i_s)^{45}-1}{45 . i_s} . \frac{1}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-45)}{\sum_{n=0}^{44} \frac{(1+i_s)^n}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-65)} \quad \boxed{8}$$

To convert equations 5, 6, and 8 into static actuarial models, for a person who retires at 65 in year t, all that is required is to substitute ${}_np_{20}^{\nearrow}(t-45)$ for ${}_np_{20}^{\uparrow}(t)$.

Moving on to a model for the substitutive text of the reform, also from Table 1 it was seen that the minimum contribution time was reduced to 15 years, that the minimum age for women fell to 62, and that there were changes in the way the retirement benefit was calculated. From the alteration made in the retirement benefit calculation and from the modeling conditions imposed, both sexes would receive 100% of the mean of their respective contribution salaries. Therefore, if $c^{s,m}$ is the balanced contribution rate given the substitutive text of the reform for a man who retires at 65 in calendar year t, in a dynamic actuarial context, $EPVC^{s,m}$, $EPVB^{s,m}$, and $B_{65}^{s,m}$ can be defined as:

$$EPVC^{s,m} = \sum_{n=0}^{44} c^{s,m} . S_{20} . \frac{(1+i_s)^n}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-45) \quad \boxed{9}$$

$$EPVB^{s,m} = \sum_{n=45}^{\omega-21} B_{65}^{s,m} . \frac{1}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-45) \quad \boxed{10}$$

$$B_{65}^{s,m} = \frac{S_{20}}{45} . \frac{(1+i_s)^{45}-1}{i_s} \quad \boxed{11}$$

For a women who retires at 62 in calendar year t, $EPVC^{s,w}$, $EPVB^{s,w}$, and $B_{62}^{s,w}$ are defined as:

$$EPVC^{s,w} = \sum_{n=0}^{41} c^{s,w} . S_{20} . \frac{(1+i_s)^n}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-42) \quad \boxed{12}$$

$$EPVB^{s,w} = \sum_{n=42}^{\omega-21} B_{62}^{s,w} . \frac{1}{(1+i)^n} . \ {}_np_{20}^{\nearrow}(t-42) \quad \boxed{13}$$

$$B_{62}^{s,w} = \frac{S_{20}}{42} . \frac{(1+i_s)^{42}-1}{i_s} \quad \boxed{14}$$

The balanced contribution rates and the conversions for the static actuarial model, for both cases, are carried out in a similar way to that explained for the original text of the reform and, consequently, can be omitted without loss. Finally, for all the scenarios under evaluation, the calculations are carried out considering five possible calendar years for retirement (t), namely: 1997, 2007, 2017, 2027, and 2037. This enables a longitudinal analysis in a 40-year spectrum, starting in the hypothetical case of a reform starting in Fernando Henrique Cardoso's government and covering projections for the next two decades.

4. RESULTS AND DISCUSSIONS

Based on the models and assumptions discussed in the previous section, this section presents the values of the balanced social security contribution rates for planned retirement at the minimum age established by the original text of the PEC n. 287-A and by its substitutive text, hypothetically, as if the reforms were effectively initiated and without transition stages in the respective years of evaluation.

Table 2 presents a summary of the balanced contribution rates found in each analysis scenario. It is perceived that these generally tend to increase, by approximately one percentage point every passing decade. This reveals the effect that the reduction in mortality has on pension costs.

Table 2
Balanced social security contribution rates for planned retirement at the minimum age, for men and women, based on the use of the dynamic and static actuarial models and the original and substitutive texts of the reform, for retirements in the years 1997, 2007, 2017, 2027, and 2037

Year of retirement	Men		Women	
	Rate considering the original text	Rate considering the substitutive text	Rate considering the original text	Rate considering the substitutive text
		Dynamic model		
1997	9.52466%	9.92152%	12.70728%	16.96872%
2007	10.64380%	11.08730%	13.94842%	18.34927%
2017	11.64753%	12.13285%	15.01278%	19.54375%
2027	12.64670%	13.17364%	15.93192%	20.55914%
2037	13.70137%	14.27226%	16.74664%	21.45898%
		Static model		
1997	9.20491%	9.58845%	12.12639%	16.06399%
2007	10.54276%	10.98204%	13.52211%	17.66133%
2017	11.72579%	12.21437%	14.73183%	19.01560%
2027	12.65324%	13.18046%	15.57853%	19.97269%
2037	13.59936%	14.16600%	16.34591%	20.83832%

Source: *Elaborated by the author based on data from the United Nations (2017).*

This increase found in the value of the contribution rates over the decades highlights the important role of applying the automatic adjustment mechanisms, as in the case of linking increases in the minimum retirement age to increases in life expectancy at the age of 65 years-old. Supposing, for illustrative purposes, that the minimum age (whether considering the original text or the substitutive one) had come fully into effect in 2017 and that life expectancy at the age of 65 years-old, for both sexes, increased by approximately one year between 2017 and 2027, then the minimum retirement age would change to 66 (for both sexes) if considering the original text or to 66 for men and 63 for women if considering the substitutive text. In this spirit, and having carried out the appropriate adjustments in the models, the contribution rates in 2027 for men would be 11.84 and 12.21% for the original and substitutive texts, respectively (and no more than 12.65 and 13.17% if retirement occurred at 65 in 2027, as presented in the static model of Table 2), while for women it would be 15.04 and 19.26%, respectively (against the 15.93 and 20.56% of Table 2), returning to levels closer to those of 2017. So, this strategy would avoid wide variations in the required social security contributions over time, keeping the rates at a more stable level. This discussion is also consistent with the findings of Souza (2018).

For a man, in the dynamic model, the contribution rate considering the original text of the PEC, if retirement occurred at 65 in 2017, would be around 11.65%. Thus, considering that currently, depending on the salary level, social security contribution rates vary from 28 to 31%, if planned retirement at the minimum age represented (for the respective ranges) around 38 and 42% of the total cost of retirement (considering retirement benefits due to invalidity, pensions etc.), the system would be actuarially fair for men. For example, for a worker who pays an 11% contribution, added to 20% from the employer, if the cost of planned retirement corresponded to less than 42% of the total cost to cover expected pension benefits, then the expected present value of the flow of contributions would be lower than the expected present value of the flow of benefits. In contrast, if the costs of planned retirement corresponded to more than 42% of the total cost, then the 31% rate would be excessive.

Based on their original assumptions, Gouveia et al. (2018) indicate that this cost would be at the 56% level, which in a first analysis would indicate that the social security contribution rates in effect, on their own and from an actuarially fair viewpoint, would be sufficient to cover the main expected retirement benefits, such as planned retirement, invalidity, and pensions. However, also according to the authors, changes in other demographic assumptions could negatively affect these values and even alter the conclusion obtained, depending on the level of variation between the assumptions adopted. So, this point reveals the need to develop official statistics for other demographic assumptions (such as entry into invalidity and disabled person mortality, for example) and, especially, to continue monitoring them over time, in order to also enable their dynamic evaluation and obtain more accurate conclusions.

In addition, between 1997 and 2037 (according to Table 2), an increase of around 44% would be expected in the contribution rate, which would rise from approximately 9.53% (in 1997) to 13.70% (in 2037). Similar results are obtained if retirement was treated according to the substitutive text of the reform, with the level of the contribution rates being slightly higher, since a worker would then earn 100% of the mean.

For women, also according to the dynamic model and based on the original text of the reform, the growth in the contribution rate would be proportionally lower, since these already start from a higher level. The expected increase between 1997 and 2037 would be approximately 32%, rising from 12.71% to 16.75%. In addition, considering retirement at 65 in 2017, the rate would be 15.01%. This difference between the female and male rate is a reflection of the higher life expectancy of women. So, considering the original text of the reform and the rates currently in effect, if planned retirement at the minimum age for women (respecting the contribution ranges) represented around 49 to 54% of total retirement cost, the contribution rates applied would be fair.

However, also according to the original assumptions of Gouveia et al. (2018), this cost would be at the 70% level; that is, women would be charged too much. According to the authors, this result would partly be a reflection of the fact that women would have lower pension costs (in general) than men. Thus, added to the arguments of a double work shifts and inequalities in the labor market, these findings would also support the need for a revision in the original text of the reform in favor of women, as occurred in the substitutive text, with the reduction of the minimum age for them, in response to the loss of allowance in the social security factor formula. Therefore, as Afonso and Zylberstajn (2017) observed, the reform, in the original molds, would have greater impacts for women. Other discussions about the controversial debate regarding sex in pensions and the trade-off between social and actuarial fairness are found in Marri, Wanjnman, and Andrade (2011), Costanzi and Ansiliero (2017), and Mostafa, Valadares, Souza, Rezende, and Fontoura (2017).

Considering the substitutive text, with the minimum age being reduced to 62 for women, the contribution rate would be 19.54% and the increase, between 1997 and 2037, would be approximately 27%. This rise in the cost of planned retirement is the result of the reduction in the expected contribution time and increase in the expected time for receiving the benefits. In addition, based on the substitutive text of the reform and considering the contribution rates currently in effect, if planned retirement at the minimum age (of 62) for women represented around 62 to 70% of the total cost of retirement, the rates in effect would be actuarially fair.

Comparing the dynamic and static models, it is found that the rates according to the dynamic model are typically higher than those obtained by the static model, with the difference being greatest for women (due to their survival profile), especially when retirement is regulated by the substitutive text of the PEC. For women, for example, all the differences are greater than 0.5 percentage point. At first, these differences may appear small, but in a system with millions of taxpayers and in a long-term analysis, this variation in fundraising can be significant. In addition, it is perceived that there is an initial tendency for a fall in the difference in contribution rates in the dynamic and static contexts with the passing decades and that this tendency becomes one where there is an increase again in the last analysis period. This process is associated with the change in the mortality profile that has occurred in the country.

As Souza and Rêgo (2018) highlight, it is a global tendency for less developed nations to obtain increases in life expectancy, with a reduction in mortality at younger ages and, as they reach higher levels of longevity, the gains in life expectancy start to be more influenced by the improvements in the health conditions of the elderly. Thus, with the increases in life expectancy of the Brazilian population, it would be natural to expect the difference presented to continue to increase, which reveals the relevance of the dynamic analysis. Formally, in the contributory period, and supposing retirement at 65 (in year t), the static model would overestimate the expected contributions, since $p_{20+n}(t) > \mathrm{p}_{20+n}(t-45+n)$, for $0 \leq n < 45$. In contrast, since the flow of benefits is also taken at present value at the age of 20, it is influenced by the previous and subsequent periods to the retirement age – and it is known that, from 65 onwards, $p_{65+n}(t) < p_{65+\mathrm{n}}(t+n)$, for $0 < n \leq \omega - 66$ – where its expected value can be increased or decreased. Therefore, as the ratio between the flow of benefits and that of contributions is adopted to calculate the contribution rate, the static model can both underestimate and overestimate the results in comparison to the dynamic model. So, if the gains in life expectancy are more influenced by the reduction in mortality at more advanced ages, this would lead to increases in the difference in the rates found by the dynamic and static models with the passing of time.

Therefore, in addition to the values found or setting out the criticisms or defenses of the reform, this article reveals the importance of using dynamics models in actuarial studies regarding pensions and encourages strengthening the national literature in the area.

4.1. Sensitivity Analysis

As Trowbridge (1989) teaches us, actuarial calculations are based on a set of premises and, indeed, the results obtained are as good as the assumptions adopted. Thus, even when seeking to follow the main premises adopted in the national literature, it is beneficial to present some sensitivity analyses of the parameters adopted. Hence, variations in the real interest and the salary growth rates are discussed, as well as mortality projections based on the moment of retirement. The analyses are conducted considering the case in which the workers retire (at the minimum age) in 2017.

Tables 3 and 4 present, respectively, the actuarially fair contribution rates before the variations in the real interest rate and in the real salary growth rate. It is perceived that, since they occur during the whole analysis period, variations in the real interest rate cause the greatest impacts on the value of the actuarially fair contribution rate, when compared with those caused by alterations of the same magnitude in the salary growth rate. In addition, as expected, increases in the interest rate cause a reduction in the fair contribution rate, while increases in the salary growth rate also lead to increases in the actuarially fair value.

According to Table 3, if the real interest rate adopted were 2% p.a., the balanced contribution rate would be around 16% for men and more than 20% for women, reaching an upper threshold of 27% based on the dynamic model and considering the substitutive text. In contrast, if the rate considered were 4% p.a., the balanced contribution rates for men would be around 8%, while for women they would be around 10% based on the original text and 13% considering the substitutive text.

Table 3
Sensitivity analysis of the balanced social security contribution rates for planned retirement at the minimum age in 2017, for men and women, based on the use of the dynamic and static actuarial models and the original and substitutive texts of the reform, given the variations in the real interest rate.

Real interest rate	Men		Women	
	Rate considering the original text	Rate considering the substitutive text	Rate considering the original text	Rate considering the substitutive text
Dynamic model				
2.0%	16.31195	16.99162	21.19038	27.37749
2.5%	13.79527	14.37007	17.84826	23.13828
3.0%	11.64753	12.13285	15.01278	19.54375
3.5%	9.818219	10.22731	12.61066	16.49727
4.0%	8.263198	8.607498	10.57880	13.91676
Static model				
2.0%	16.29998	16.97915	20.62755	26.41651
2.5%	13.83756	14.41413	17.44595	22.42219
3.0%	11.72579	12.21437	14.73183	19.01560
3.5%	9.918603	10.33188	12.42053	16.11255
4.0%	8.375414	8.724389	10.45584	13.64082

Source: *Elaborated by the author based on data from the United Nations (2017).*

Table 4
Sensitivity analysis of the balanced social security contribution rates for planned retirement at the minimum age in 2017, for men and women, based on the use of the dynamic and static actuarial models and the original and substitutive texts of the reform, given the variations in the real rate of salary growth.

Real rate of salary growth	Men		Women	
	Rate considering the original text	Rate considering the substitutive text	Rate considering the original text	Rate considering the substitutive text
Dynamic model				
1.0%	10.97486	11.43215	14.21801	18.65164
1.5%	11.30606	11.77715	14.61034	19.09306
2.0%	11.64753	12.13285	15.01278	19.54375
2.5%	11.99797	12.49788	15.42364	20.00199
3.0%	12.35592	12.87075	15.84110	20.46597
Static model				
1.0%	11.08088	11.54258	13.97854	18.17264
1.5%	11.39881	11.87376	14.35065	18.58994
2.0%	11.72579	12.21437	14.73183	19.01560
2.5%	12.06051	12.56304	15.12045	19.44798
3.0%	12.40155	12.91829	15.51477	19.88536

Source*: Elaborated by the author based on data from the United Nations (2017).*

Finally, Table 5 shows the effect that deviations in the mortality projections based on the minimum retirement age can cause on the contribution rates. For this, the cohort mortality tables in the dynamic model were improved and worsened, thus enabling different mortality projections from 2017 onwards. According to Caldart, Motta, Caetano, and Bonatto (2014), the process of worsening a mortality table consists of increasing the mortality rates and, consequently, reducing life expectancy. Improvement, in contrast, would lead to an increase in life expectancy. It is worth highlighting that this sensitivity analysis only focused on the dynamic model, since the data on mortality up to 2017 are known and the static model, as mentioned, assumes the static mortality hypothesis.

In the dynamic model and based on the original text, for men and women, the values of $p_{x+t}(2017+t)$, for all $x \geq 65$ and $t \geq 0$, were substituted for those from the years $2022 + t$ and $2027 + t$ – thus improving the table from 65 years old onwards – and for the values from $2012 + t$ and $2007 + t$ – thus worsening the table. Therefore, $e_{65}^{\nearrow}$ (2017)rises to the levels of 2022 and 2027 or slides to the values of 2012 and 2007. For the substitutive text, the adjustments (for women) were carried out from 62 years old onwards.

Table 5
Sensitivity analysis of the balanced social security contribution rates for planned retirement at the minimum age in 2017, for men and women, based on the use of the dynamic and static actuarial models and the original and substitutive texts of the reform, worsening and improving the mortality tables starting from the minimum retirement age.

Adjustment in the mortality table	Dynamic model			
	Men		Women	
	Rate considering the original text	Rate considering the substitutive text	Rate considering the original text	Rate considering the substitutive text
2007	11.12621	11.58981	14.42259	18.83123
2012	11.39241	11.86710	14.72464	19.20158
2017	11.64753	12.13285	15.01278	19.54375
2022	11.90422	12.40023	15.28822	19.87162
2027	12.16798	12.67498	15.55173	20.18619

Source*: Elaborated by the author based on data from the United Nations (2017).*

From Table 5, it is observed that, as expected, increases in life expectancy at the time of retirement would raise the value of the social security contribution rate. For example, if cohort life expectancy at the age of 65 years-old (or at

62 in the case of women based on the substitutive text), in 2017, were raised to the levels projected for 2027, the value of the fair rate would increase by approximately 0.5 percentage point. As Dickson, Hardy, and Waters (2013) highlight, this type of analysis (in particular that of the improvement) is relevant since in various countries mortality has declined more quickly than has been forecasted, which in the context under analysis would raise the value of expected future benefits and, indeed, social security contribution rates.

5. CONCLUSIONS

After Dilma Rousseff's impeachment, in the middle of 2016, Michel Temer's government began with the proposal to carry out various reforms in the country, one of the most notable being the social security reform, as established in PEC n. 287-A. This reform would aim to bring the RPPS rules closer to those of the RGPS, establish the minimum retirement age, revise the way retirement benefits and pensions are calculated, and define transition rules, among other arrangements. Thus, from a fiscal viewpoint, the government would hope to reduce the impacts of pension spending on the public accounts.

The arguments adopted to support the need for pension reform are typically based on the demographic changes that the country has undergone in recent decades with the reduction in the birthrate and, especially, the increases in life expectancy. Thus, this article aimed to contribute both to the current discussion regarding social security reform and to strengthen the national literature with regards to the use of dynamic actuarial models in social security evaluations.

Based on the original assumptions, it was found that the balanced contribution rates calculated by the dynamic actuarial model are typically higher than those obtained by the static model, especially for women. In addition, this difference is expected to rise as increases in life expectancy become more influenced by the reduction in mortality at more advanced ages, which reveals the need to use dynamic actuarial models in social security studies, particularly due to the long-term nature of the analyses. In addition, based on the proposed texts (original and substitutive), there are indications that the rates currently charged would be excessive for men. In turn, the rates would be excessive for women based on the original text and closer to the actuarially fair value based on the substitutive text.

From the findings and discussions developed in this article, it is understood that to enable more precise and complete studies it is important to develop official dynamic tables and regularly update them (with each demographic census, for example), and not only with regards to mortality, since other demographic assumptions also have an important influence on the evaluation of expected pension benefits (such as in the case of disabled person mortality and disability rate tables) and, therefore, would also require monitoring of their dynamics and regular official disclosures.

In addition, it is worth highlighting that the analyses regarding actuarial fairness presuppose some type of resource capitalization (even if fictitious), therefore they do not consider the ageing population structure. However, since Brazil currently adoptes a pay-as-you-go system, the effects of the reduction in the birthrate combined with the increases in life expectancy are reflected in the actuarial equilibrium of the system, exerting greater fiscal pressure on future generations. Thus, an actuarially fair contribution rate would not imply actuarial equilibrium of the system.

At this point, it is wise to emphasize limitations of the research and make indications that could guide the reader towards a more in-depth understanding and future studies, especially with regards to the hypotheses adopted and the simplicity of the exercise. Initially, the study carried out in this article foresaw a 100% contribution density; that is, there would be no gaps caused by periods of unemployment or informality. Discussions were also not carried out regarding the transition rules. In this sense, the study from Martins and Campani (2019), which evaluates actuarial gains and losses for beneficiaries during the transition period of the reform in light of different scenarios, including work trajectory, is a relevant reference. Analyses regarding linking the pension floor to the minimum wage also warrant future actuarial studies. In this sense, studies such as Tafner (2012) indicate that readjustments of the minimum wage are one of the villains of increases in pension spending and, consequently, of the system's sustainability.

Another point to highlight is the possible low quality of the data on mortality for more advanced ages in Brazil, due to the uncertainty regarding the ages reported and the imputation of absent data (Gomes & Turra, 2009; Turra, 2012). Thus, as Turra (2012, p. 164) states, "the lack of knowledge regarding the true adult mortality structure in Brazil may lead to inaccurate projections concerning the behavior of longevity in the country". The risk that the projections made do not correspond to the real behavior of longevity (whether it is underestimated or overestimated) is known in the literature as longevity risk and has attracted much attention from the literature (Wills & Sherris, 2010). Awareness of longevity risk also reinforces the need to regularly update the projections and implement automatic adjustment mechanisms capable of responding when deviations are detected.

Finally, as indicated by the OECD (2017), there is demand from the working classes for pension systems that support flexible work schedules, in particular for more advanced ages, in which the employee could benefit from a lower pension and remain active in the market part time, for example. In this spirit, benefit reduction mechanisms (such as the social security factor) follow as alternatives to the minimum retirement age policies, and research that aims to review the social security factor (in the Brazilian case), adequately incorporating cohort life expectancy into its formulation and evaluating the impacts of this measure, would certainly contribute to the current debate on pension reform in Brazil.

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