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Executive branch federal civil servant mortality by sex and educational level – 1993/2014

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ABSTRACT

Life tables have been elaborated throughout much of human history. However, the first life table to use actuarial concepts was only constructed in 1815 by Milne for the city of Carlisle in England. Since then, numerous tables have been elaborated for different regions and countries, due to their crucial importance for analyzing various types of problems covering a vast range of possibilities, from actuarial studies to forecasting and evaluating demands in order to define public policies. The most common problem nowadays in an actuarial calculation is choosing a suitable table for a given population. Brazil has few specific tables for the pensions market and has been using imported tables that refer to other countries, with different cultures and different mortality experiences. Using data from the Integrated Human Resource Administration System, this table constructs life tables for Executive branch federal civil servants for the period from 1993 to 2014, disaggregated for sex, age, and educational level (high school and university). The international literature has recognized differences in mortality due to sex, socioeconomic differences, and occupation. The creation of the Complementary Pension Foundation for Federal Public Servants in 2013 requires specific mortality tables for this population to support actuarial studies, healthcare, and personnel policies. A mathematical equation is fitted to the data. This equation can be broken down into infant mortality (not present in the data), mortality from external causes, and mortality from senescence. Recent results acknowledging an upper limit for old age mortality are incorporated into the adjusted probabilities of death. Assuming a binomial distribution for deaths, the deviance was used as a figure of merit to evaluate the goodness of fit of the observed data both to a set of tables used by the insurance/pensions market and to the adjusted tables.

Keywords: mortality tables, federal civil servants, Heligman & Pollard model, educational attainment effect, sex differentials in mortality.

1. INTRODUCTION

Life tables have been elaborated throughout much of human history. However, the first life table to use strictly actuarial concepts was constructed in 1815 by Milne for the city of Carlisle in England. Since then, numerous tables have been elaborated for different regions and countries, due to their crucial importance for analyzing different types of problems covering a vast range of possibilities, from actuarial studies (Caldart, 2014) to forecasting and evaluating demands in order to define public policies. The most common problem nowadays in actuarial calculations is choosing a suitable table for a given population. The creation of the Complementary Pensions Foundation for Federal Public Servants (Funpresp) in 2013 requires specific mortality tables for this population to support actuarial studies, healthcare, and personnel policies.

Constructing a specific life table for a population group presents two problems. The first is the dataset in itself, containing information on deaths and the population at risk. Here it is possible to use cohort or cross-sectional data. The advantage of using cohort data lies in being able to observe the mortality rates of a single group at different ages. The disadvantage is the time needed to gather this data, as it is necessary to wait a whole generation from the birth to the death of the last member. With cross-sectional data, the data gathering time is reduced, but they observe deaths among different generations at different ages. The usual way is to construct what is called a synthetic cohort, using hypothetical individuals that would be exposed, at each age, to the force of mortality at a given time.

The second problem involves choosing a suitable model to describe some mortality function. Deaths can be considered as random variables with a binomial distribution, $B(N,q)$, with the size parameter, N, being known (population exposed to risk) and the probability parameter, q, being unknown and still to be estimated. It is common to work with non-parametric models, in which the functions for the table for each age (or age group) are directly estimated from the data. Assuming that contiguous age groups (or contiguous ages) should present similar values for the functions, some type of smoothing considering the ages is usual. For this, various graduation techniques have been developed. Copas and Haberman (1983) divide the graduation methods into three main groups: graphical methods, parametric methods, and sum and adjusted means methods. Abid, Kamhawey, and Alsalloum (2006) divide the graduation actuarial methods into nine main blocks: graphical method, summation method, Kernel's method, the method of osculatory interpolation, the spline method, the curve fitting or parametric method, graduation by reference to a standard table, difference equation method and linear programming method. On the other hand, each one of these approaches can incorporate time series variations or consider a particular point in time; that is, referring to a particular date.

The United Nations has created families of model tables, grouping those with similar characteristics (United Nations, 1983). There are four families (North, South, East, and West) indexed by a parameter. Although these tables have been created based on observation of 158 life tables, the indexation by a single parameter makes their use relatively limited. In contrast, there has been an extensive offering of flexible parametric models to describe the forces of mortality for different ages. Some models aim to describe only adult mortality or some specific age group. The first more simplistic models assumed a maximum age and the functions that described the monitoring of the cohort data were of the type: $l_x = 1 - \left(\frac{x}{M}\right)^n$, in which x is age, M is the maximum achievable age for the population, and n is an adjustment constant to be determined for the specific population [see, for example, de Moivre (1718) and de Graaf (1729) cited by Duchene and Wunsch (1988)].

Gompertz (1825) proposes a model that, besides the random mortality that would affect young and old in the same way, adds a force of mortality related with senescence. There is no hypothesis for maximum lifespan. The resulting formula is:

$$l_x = ck^{q^x} \quad (1)$$

in which x is age and the other parameters are constant in the equation and are still to be estimated.

Also in the same century, various authors proposed generalizations of this formula, mainly trying to better fit extreme ages (the youngest and oldest). The proposed models based on the Gompertz formula were made more and more complex, although in the end none of them was completely satisfactory.

Other authors used various principles to formulate laws of mortality, for example using the Weibull distribution. In such cases, these authors (Morlat, 1975, cited by Duchene and Wunsch, 1988) assume that individuals are a composition of multiple and complex dynamic systems that interact with each other, each one with a Weibull distribution with a specific parameter. The combination of the various Weibull distributions has the same probability distribution. In this distribution, the force of mortality decreases with age like a hyperbola, while the Gompertz function assumes a constant force of mortality. The next stage was to propose models in which the mortality of each age group (or group of causes) presented a specific behavior, and therefore had to be described by a different equation.

Obviously, the level and structure of mortality vary from population to population, and even in a specific population, they vary in time. Studies on mortality rates have been developed considering the influence of economic factors such as wealth. However, due to the difficulty of measuring this variable, it is common to use another variable that is highly correlated with income, such as education or occupation, which are more easily measured [see Vallin (1980)]. Masters, Hummer, and Powers (2012) explain the persistence of the importance of different educational levels for mortality, both for causes and for the aggregate.

Another aspect regarding mortality tables disaggregated by professional categories is common in developed countries. For example, in Great Britain statistics have been collected and published for more than 100 years, classifying workers into five socioeconomic groups: Professionals, Managerial & technical intermediate, Skilled non-manual, Skilled manual, Partly skilled, and Unskilled. Some countries develop specific mortality tables for the civil servant population (Andreone, 2011; Canada, 2014; Daric, 1951).

These studies have also been carried out for mortalities from specific causes. For example, Terris (1967) studied deaths from liver cirrhosis among different occupational groups in the United States of America and in other countries during the 1950s. Among his findings, Terris concluded that among 20- to 60-year-old men, manual workers (except those in agriculture) and those who were semi-qualified had high mortality levels, of 48% and 18% above the American average, respectively. In contrast, during the same period in England and Wales it was observed that those groups with a higher educational level had twice as much chance of dying from cirrhosis than the less educated. The difference between these countries is attributable to the legislation for taxation. Alcoholic drinks are more heavily taxed in the countries mentioned than in the United States of America.

The main obstacle to constructing a life table using Civil Registry data (for information on deaths) and Censuses (for the population at risk) in Brazil and in other countries in a similar situation lies both in the level of coverage of deaths and in the coverage and quality of the census information, although it is possible to estimate a corrector that uses any one of the various techniques that exist for estimating the levels of death coverage of the civil registry (Bennett & Horiuchi, 1981; Brass, 1975; Courbage & Fargues, 1979; Preston, Coale, Trussel & Weinstein, 1980). These techniques assume a uniform error for all ages, or at least for the age groups above a certain age (usually 5 or 10 years). There is, however, evidence that these errors would be greater for the extreme groups: children and the elderly. Another problem is the use of data from different sources and possibly with different measurement and coverage errors. In Brazil, the problem of digit preference is notorious. It is common for people, especially the most elderly and those from a lower socioeconomic level, to state their age or year of birth by rounding the numbers to values ending in 0 or 5.

Brazil has few specific tables adapted to the insurance and pensions markets and has used imported tables that refer to other countries, with different cultures and different mortality experiences. In Brazil, the use of administrative data for calculating mortality rates already has some precedents. Conde (1991) constructed a life table for employees of the Attílio Francisco Xavier Fontana Foundation. Beltrão, Sobral, Leal, and Conceição (1995) computed a table for Banco do Brasil employees for the period from 1940 to 1990, based on its employee pension fund's register. Ribeiro and Pires (2001) extended this table to include data up to 2000. Beltrão and Sugahara (2002) constructed tables for federal civil servants using data from the Integrated Human Resource Administration System (Siape) [by 2017, the system will be gradually substituted by another more comprehensive Integrated People Management System (Sigepe)]. Beltrão and Sugahara (2005) used administrative data from the Superintendence for Private Insurance (Susep) to fit a life table to the population covered by private insurance. Oliveira, Frischtak, Ramirez, Beltrão, and Pinheiro (2012) replicated the study with more recent data. Using administrative data from the São Paulo State Office of Planning, Silva (2010) estimated tables by sex and educational level for the state's civil servants. Borges (2009) returned to the estimates for federal civil servants, but calculated multiple decrement tables, including, besides death, the onset of invalidity and the probability of exoneration from the civil service. The advantages of using administrative data lie mainly in the fact that the denominators and numerators are derived from the same source and so there is not the problem of under-registration or digit preference. Moreover, as the main use of these records is for staff payment, belief in the reliability of the records is well based.

In this study, using the data from Siape, probabilities of death for active and retired Executive branch federal civil servants were estimated, extending the work of Beltrão and Sugahara (2002) and Borges (2009) and incorporating an expanded database to include 10 more years, thus obtaining more accurate estimates. These estimates contribute to forming a set of mortality tables with experiences based on national data, and specifically, they could support studies regarding public policies involving federal civil servants.

This article is composed of four sections. The first is this introduction. The second describes and presents the development of the study and the third section includes the comments and conclusions. The last section contains the bibliography used. The Annex presents the values of the estimated tables for sex and educational level.

2. DEVELOPMENT

This section describes the source of the data used and the variables considered in the study and traces a profile of the contingent and of the public servant deaths found in the Siape database and used in calculating the probabilities of death. It also presents an adjusted model and the estimated parameters, as well as comparing the estimated tables according to sex and educational level and comparing these estimated tables with those used by the market.

2.1 Data source

With the reform of the State that started in 1995 (Brazil, 1995) and as part of a proposal for "reconstruction of the public administration on modern and rational foundations", various information systems were developed to help in government management. Among these systems, a single system was created for the whole civil service in order to manage payroll and keep records on federal civil servants (Siape).

The system contains various files organized into tables with various types of records, in which the civil servant's registration is key for concatenation of the same records in the different tables. In volume, in December 2014 the Siape archive, the reference database for the data in this study, was composed of 1,447,670 observations corresponding to active, retired, and deceased federal civil servants. At the same time, the personnel list contained 1,207,106 active and retired workers and pension providers. Using the Siape personnel database, a summarized file was generated, containing, for each one of the registration records (including active, retired, and deceased employees, whether these were pension generators or not – information not provided), relevant information such as sex, age, educational level, and entity.

Some variables were chosen from those in the archive to use in this study. Some other variables were created using the information available. As an administrative record, Siape presents the advantages of working with a single source. Thus, the numerator and the denominator of the probabilities of death are derived from the same source, as well as there not being the problem of under-registration or digit preference.

2.2 Distribution of the Federal Civil Servants

Using the Siape data, Table 1 presents the contingent of public employees classified by sex and situation (active, retired, exonerated, deceased, and others), in December 2014. The active and retired individuals correspond to around 65% of the group, with the active ones constituting a little more than half of these, 38.4%. Of the active employees, males make up the majority. Of those compulsorily retired (with full or proportional earnings), men also make up the majority. Of those retired due to invalidity with full earnings, men are the majority, and of those with proportional earnings, women are the majority. As expected, the contingent of deceased individuals is also greater among the men, since both male mortality and the contingents exposed to risk are more significant.

Table 1 *Classification of Executive branch federal civil servants in the register in December 2014, by sex and situation*

Current situation of civil servant or at time of death	Sex		Total	%
	Men	Women		
Active permanent employee on loan or not	309,181	246,758	555,939	38.4
Retired due to invalidity with full earnings	14,870	9,940	24,810	1.7
Retired due to invalidity with proportional earnings	5,105	6,021	11,126	0.8
Compulsory retirement with full earnings	675	279	954	0.1
Compulsory retirement with proportional earnings	4,070	2,137	6,207	0.4
Voluntary retirement with full earnings	123,639	124,639	248,278	17.2
Voluntary retirement with proportional earnings	40,411	52,819	93,230	6.4
Exonerated or dismissed	86,027	56,244	142,271	9.8
Deceased	296,675	68,025	364,700	25.2
Others	101	54	155	0
Total	880,754	566,916	1,447,670	100

Source: *Elaborated by the authors using data from the Integrated Human Resource Administration System (Siape).*

The values in Table 2 were obtained by classifying the population of federal civil servants by educational level and sex. As already mentioned, the literature indicates different mortalities for educational level and sex. In this text, the decision was to group the employees into two more or less equal sized groups: "higher level", corresponding to those having completed higher education, a master's, or doctorate, and "middle level", including all educational levels below.

Table 2 *Classification of the Executive branch federal civil servants in the register in December 2014, by sex and educational level*

Educational level	Sex		Total	%
	Men	Women		
0	13,522	1,117	14,639	1
Illiterate	8,685	1,061	9,746	0.7
Literate with standard courses	72,218	11,099	83,317	5.8
First level incomplete up to 4th grade incomplete	37	0	37	0
4th grade of first level complete	190	63	253	0
Elementary school incomplete	108,102	27,840	135,942	9.4
Elementary school	92,106	47,365	139,471	9.6
Second level incomplete	110	47	157	0
High school	194,202	158,348	352,550	24.4
University incomplete	1,370	792	2,162	0.1
Middle level	*477,020*	*246,615*	*723,635*	*51*
University	374,412	305,812	680,224	47
Master's	8,880	7,993	16,873	1.2
Doctorate	6,920	5,379	12,299	0.8
Higher level	*390,212*	*319,184*	*709,396*	*49*
Total	880,754	566,916	1,447,670	100

Source: *Elaborated by the authors using data from the Integrated Human Resource Administration System (Siape).*

Following the proposed disaggregation of the population analysis into two main groups according to educational level, the information with this disaggregation is presented in Figure 1. The male (in blue) middle level population (left hand side pyramid) corresponds to a little more than six million person-years, while the female (in red) population is a little more than four million. For the men, the mode is presented as the threshold with very close values between 50 and 65 years, while for the women a single mode is discernable at 50 years. The exposed populations corresponding to the higher level (right hand side of the figure) are almost five and a little more than four million for men and women, respectively; that is, the contingents of the two sexes present very close values to each other compared with the middle level. These are presented as unimodal, with a mode around 44 years, both for men and for women. It is noted that for this educational level the mode is younger than for the middle level.

Figure 1 *Sex/age distribution – population of active and retired civil servants – 1993/2014*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

Figure 2 presents, for the aggregate data between 1993 and 2014, the age pyramid of deaths in the active and retired population. The total deaths for those from the middle level (left hand side pyramid) is in the order of 173 thousand for men (in blue) and 47 thousand for women (in red). The profile of deaths for both sexes is unimodal, with the maximum at around 72 years for men and 78 for women. As for the higher level population (right hand side pyramid), total deaths are almost 46 thousand for men and 14.4 thousand for women. For this higher level population, the profile of deaths is also unimodal, with the mode at around 72 and 73, for men and women, respectively.

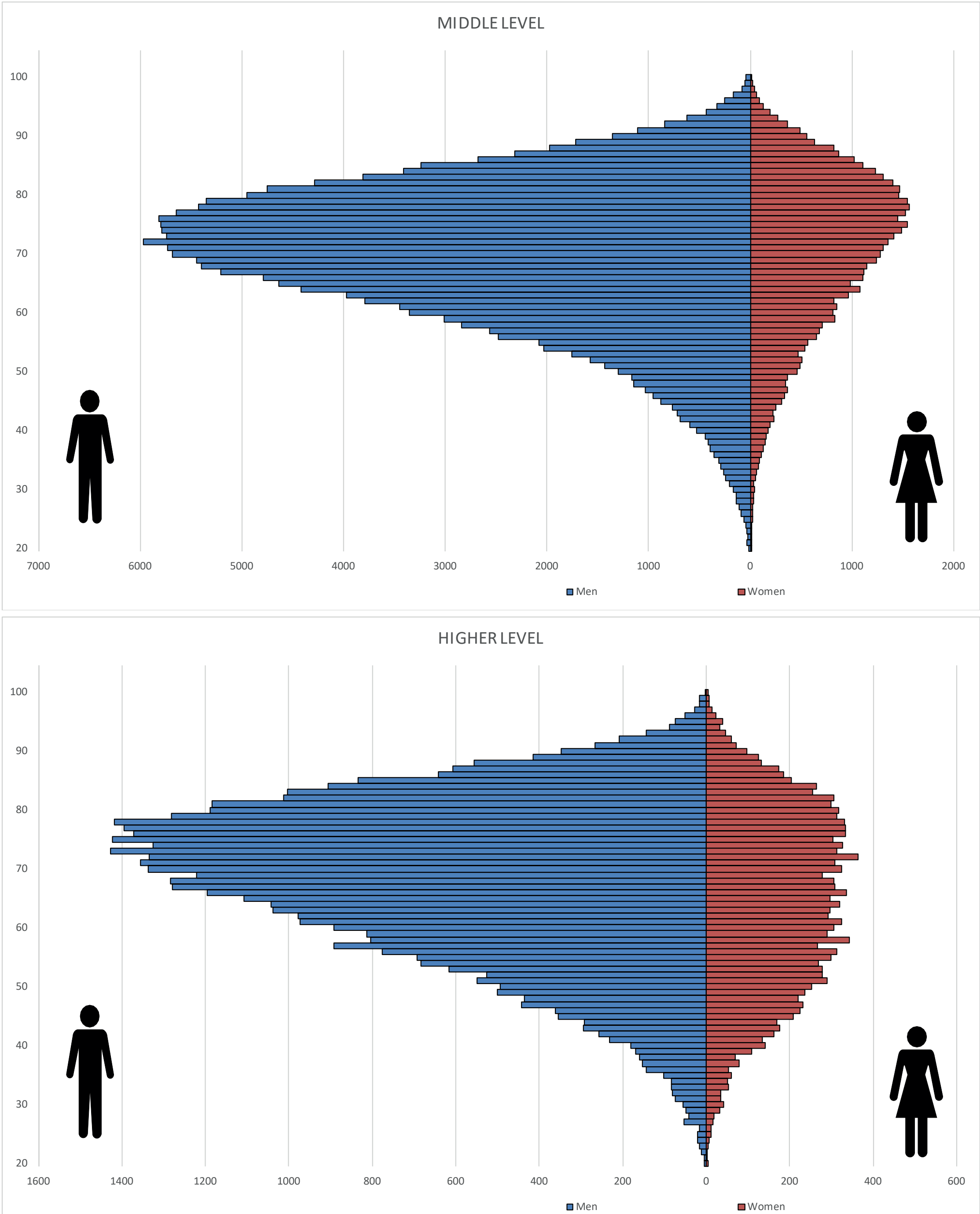

Figure 2 *Sex/age distribution – active and retired civil servant deaths – 1993/2014*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

2.3 Model Used

The following variables were used: $p_{x,s,e,t}$, for population of active and retired individuals with age *x*, sex *s* and educational level *e* (mean for year *t*) (population at risk), and $d_{x,s,e,t}$, for deaths of the population of active and retired individuals occurring with age *x*, sex *s* and educational level *e* (in year *t*). These two variables were already described in the previous section and the aggregate data can be viewed in Figure 2 for the deaths and in Figure 1 for the population at risk. For the study, the years t = 1993 to 2014 were considered. The probabilities of death by sex, age, and educational level were initially calculated using the following formula, without any correction:

$$q(x,s,e,t) = \frac{d_{x,s,e,t}}{p_{x,s,e,t} + d_{x,s,e,t}/2} \quad (2)$$

in which $q(x,s,e,t)$ is the probability of death of an individual from the population, with age x, sex s, and educational level e (in year t); $p_{x,s,e,t}$ is the population exposed to risk (of active and retired individuals) with age x, sex s and educational level e (approximated as the mean of the population at the beginning and at the end of year t). By hypothesis, inflows and outflows not through deaths are considered as uniform over the year; $d_{x,s,e,t}$ are the deaths for the population of active and retired individuals occurring with age x, sex s and educational level e (in year t). By hypothesis, deaths are also considered uniform over the year. In the case of a closed population, the denominator is reduced to the population at the beginning of the year and the distribution of deaths is exactly a binomial. With inflows and outflows occurring through exoneration and new hirings over the year (always small flows in comparison to the population), this distribution is approximated. The Poisson distribution could be used as an approximation of the binomial distribution if the product of the exposed population size and of the probability of death was a small value and the size of the population was large. In this study, this approximation is not advisable, due to the populations at the advanced ages being very sparse and the probabilities of death not being small.

Figure 3 shows the probability of death according to sex, age, and educational level estimated for the period 1993/2014. Typically, men present higher values than women and individuals from the middle level present higher values than their higher level counterparts. In particular, the probability for the population of Men – middle level (dark blue line) is the highest, but with a possible cross-over in the upper ages with the probabilities of the higher level male population (light blue line). The probabilities of death of the middle level women (red line) lie, for the young adults (less than 40 years), in second place, directly below the probabilities related to the middle level men. From around 50 years, they are overtaken by the probabilities of death among higher level men, which in the lower ages lie in third place. The probabilities for higher level women (orange line) are consistently below all of the others.

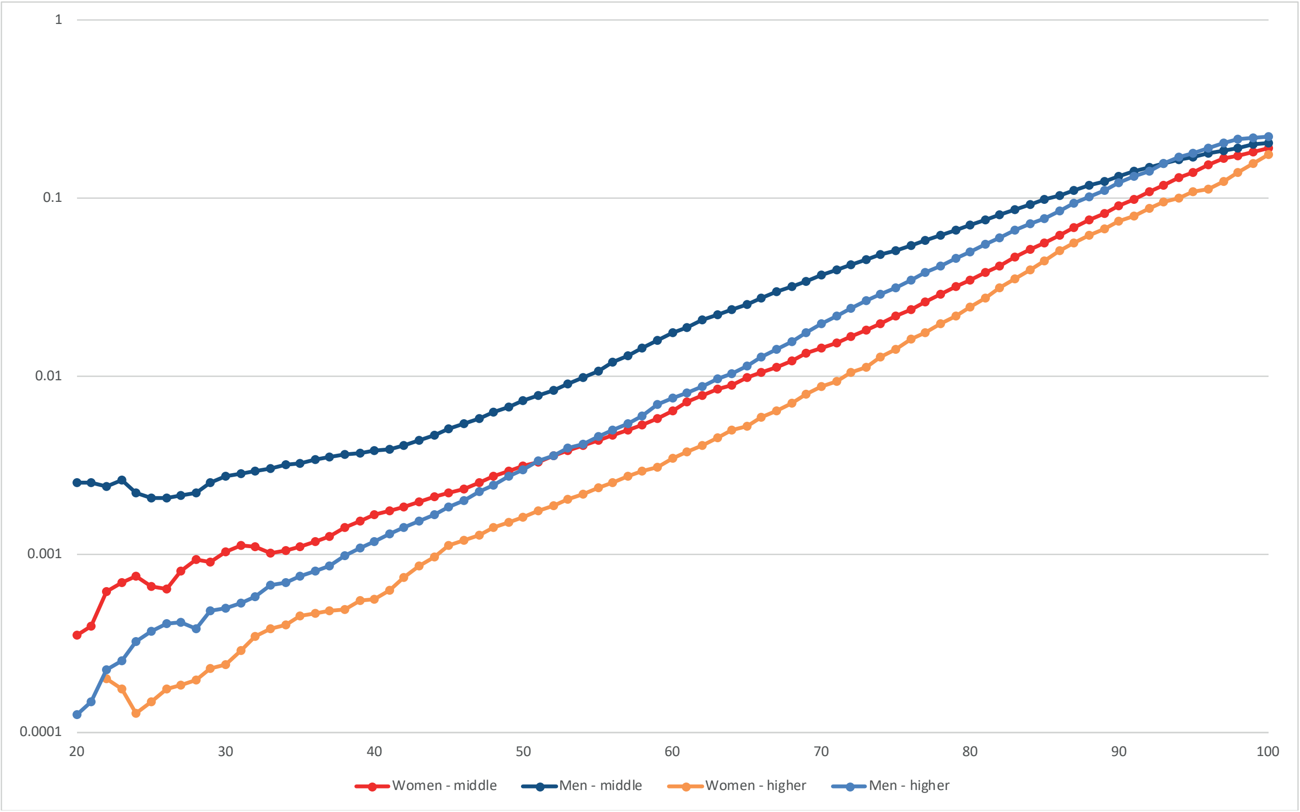

Figure 3 *Probabilities of death according to sex, age, and educational level – active and retired civil servants – 1993/2014*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

The curves suggest that it would be possible to fit a function to these possibilities.

The decision was taken to test the families of functions suggested by Heligman and Pollard (1980) and already successfully used by Beltrão and Sugahara (2002, 2005), Borges (2009), Oliveira et al. (2012), and Silva (2010).

The full model, as proposed by Heligman and Pollard (1980), includes three components:

$$q(x) = A^{(x+B)^C} + De^{-E(\ln x - \ln F)^2} + \frac{GH^x}{(1+KGH^x)} \quad \boxed{3}$$

in which the first term (with parameters A, B, and C) describes mortality in early childhood. Unfortunately, there is no information on mortality related to this segment for this population, and so this component cannot be fitted and the adjusted mortality only refers to adult mortality (including the elderly up to 100 years). Probably, with information on most years it would be possible to improve the estimates for the elderly. Data for the first component (using information on survivors' pensions) are also unlikely to be available. The second term corresponds to mortality from external causes. Deaths from external causes correspond to chapter XX of the International Classification of Diseases (Brazil, 2015). These causes of mortality mainly affect the male population and in Brazil they are the main causes of deaths among young male adults. In the data, this cause is only evident among the middle level male and female population. The D parameter is related to the level of the "bump", while the E parameter is related to its amplitude and the F parameter is a location parameter, laterally shifting the curve in the ages and at the same time characterizing the mode of this component (equal to 1nF). The last term corresponds to mortality from senescence and enables a deceleration (or acceleration) of mortality to be fitted to the individuals in old age. This term is what varies between the different families proposed by Heligman and Pollard (1980). The G parameter can be simply understood as a shift of (lnG) in the age scale. The H parameter regulates the changes in the curvatures, as all begin concave and become convex. The higher H, the earlier the inflexion occurs. The functional form of this term for another family considered by the authors is:

$$q(x) = \frac{GH^{x^K}}{(1+GH^{x^K})} \quad \boxed{4}$$

As the data for the eldest group are scarce, even though the fit has been carried out for all ages up to 100 years, there is no intention for the estimated curves to be used above 90 years. As the fitted probabilities present a cross-over between the sexes due to a fall in male mortality in the ages above 92, for ages above 90 the female probability was chosen as a reference.

Eliminating the first component, the family that best fits the data was a sum of exponentials in the form:

$$q(x) = De^{-E(\ln x - \ln F)^2} + \frac{GH^x}{(1+KGH^x)} \quad \boxed{5}$$

for middle level men and women and

$$q(x) = \frac{GH^x}{(1+KGH^x)} \quad \boxed{6}$$

for higher level men and women (eliminating the first two terms).

3. RESULTS

This section presents the fit made and compares this with the selected tables used by the insurance and pensions market.

3.1 Fits for Probability of Death

The person-years and deaths for the period 1993/2014 were considered for the parameters D, E, F, G, H, and K for men and women, as well as for each one of the educational levels (parameters D, E, and F appear only for the middle level). The estimation was carried out iteratively, using the non-linear regression analysis tool from the Statistical Package for the Social Sciences (SPSS), defining weights for the records (analysis/regression/nonlinear). The deaths observations for a particular age, educational level, and sex are assumed to be distributed as random binomial variables B ($N_{x,e,s}$, $q_{x,e,s}$), in which $N_{x,e,s}$ is the population of civil servants of a particular age *x*, educational level *e*, and sex *s*, adjusted for inflows, outflows, and deaths, all of which are assumed to be uniform over the year, and $q_{x,e,s}$ is the probability of death which needs to be determined. The non-linear regression procedure of the SPSS package does not enable the choice of this distribution (in fact, it is only possible to directly obtain optimal estimators for the normal distribution). Iteratively, estimators were calculated using weights that were inversely proportional to the standard deviation of the binomial based on the estimators from the previous stage. In the *i*–th step the weight, $weight_{x,e,s}^{(i)}$, was calculated based on the probability of death estimated in the previous step, $q_{x,e,s}^{(i-1)}$; that is:

$$weight_{x,e,s}^{(i)} = \frac{N_{x,e,s}}{q_{x,e,s}^{(i-1)} * \left(1 - q_{x,e,s}^{(i-1)}\right)} \quad (7)$$

For the first step, the population for each age, sex, and educational level were used as a weight, equivalent to assuming that the probabilities are constant for all the ages. The convergence was always quick, with five iterations at most. The stop criterion was obtaining a difference between successive estimates of the parameter lower than 10^{-10}. The K parameter was tested and shown to be statistically different from the unit for all the combinations of sex and educational level, with the exception of the population of higher level men. As this population was the only case, the decision was taken to maintain the parameter in the equation of the model for this combination. All the estimated parameters were statistically significant. For the middle level group, the ages between 20 and 100 (included) were used in the fit. For the higher level group, the age interval used was between 25 and 100 (included).

As already mentioned, the inexistence of people working for the government in lower ages than the limits used does not allow the estimation of the first component of the Heligman and Pollard model (1980), and consequently the mortality estimate for obtaining a complete table starting from age zero. One suggestion for ages below 20 (or 25) would be concatenation with tables from the Brazilian Institute for Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE), using a logit transformation to guarantee continuity. For the centenarians, although the data exists, they are very sparse and there are doubts about their reliability. There is no consensus among the specialists about what the curve related to centenarian ages should be like. There is conflicting evidence and the information is all highly dependent on the quality of the data (Caselli & Vallin, 2001; Duchene & Wunsch, 1988). The growth rate of mortality appears to slow down for the elderly, but the controversy is due to the cause. Simple facts, such as mixture of populations, each one with a specific mortality curve, can imply a deceleration and even decrease in the mortality rate as a function of age for the aggregate population.

The discussion in the literature from the Society of Actuaries (SOA, 2001, 2014) with regards to the construction of the RP tables indicates a deceleration in mortality rates in advanced ages, resulting in a plateau with a below-unit value (Gampe, 2010; Gavrilov & Gavrilova, 2011; Kestenbaum & Ferguson, 2010, cited by SOA, 2014). In this text, the same limit for men and women was assumed, similar to that adopted by the SOA when developing the RP tables. Moreover, the same threshold was assumed for both educational levels: 0.5. To guarantee this limit, the adjusted probabilities for the ages above 90 were recalculated as a weighted mean between the adjusted value and the limit value, using the value (age-90)/30 as a weight. That is, at 119 years, the value reaches almost 0.5 and the subsequent value is equaled to one unit.

Table 3 *Estimated parameters of the curve adjusted for sex and educational level*

	Level	D	E	F	G	H	K
Women	Middle	0.00031	4.00	29.00	0.00004937	1.08447	-2.0807
Men		0.00236	2.60	18.00	0.00012529	1.08582	2.8139
Women	Higher	-	-	-	0.00001629	1.09440	-3.1930
Men		-	-	-	0.00002420	1.10061	0.9314

Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

Considering that the differences for sex and for educational level are determinants for the mortality profile, in which each group follows a sex and educational level combination, it is analyzed separately; however the graphics are shown according to the civil servants' educational level.

3.2 Comparison of the Results - Sex and Educational Level

Figure 4 shows the comparisons of the results related to the adjustments of the chosen models (continuous lines) with the raw data (points) for men (in blue) and women (in red) from the middle (left hand side) and higher (right hand side) educational levels. For the ages below 40, for both sexes from the middle level, the raw data appear to be slightly above the adjusted values of the function. For the other ages, the goodness of fit of the data to the model appears to be high, especially for the oldest males. This result is less satisfactory among women for the highest ages (above 95 years), which was already expected since the larger spread is the result of the smaller population at risk. The model indicates acceleration in the probabilities of death with age which places the adjusted values slightly above those observed. For middle level men, the negative K parameter indicates mortality with decelerating growth in the higher ages. As for middle level women, the positive K parameter indicates mortality with acceleration in growth in the higher ages.

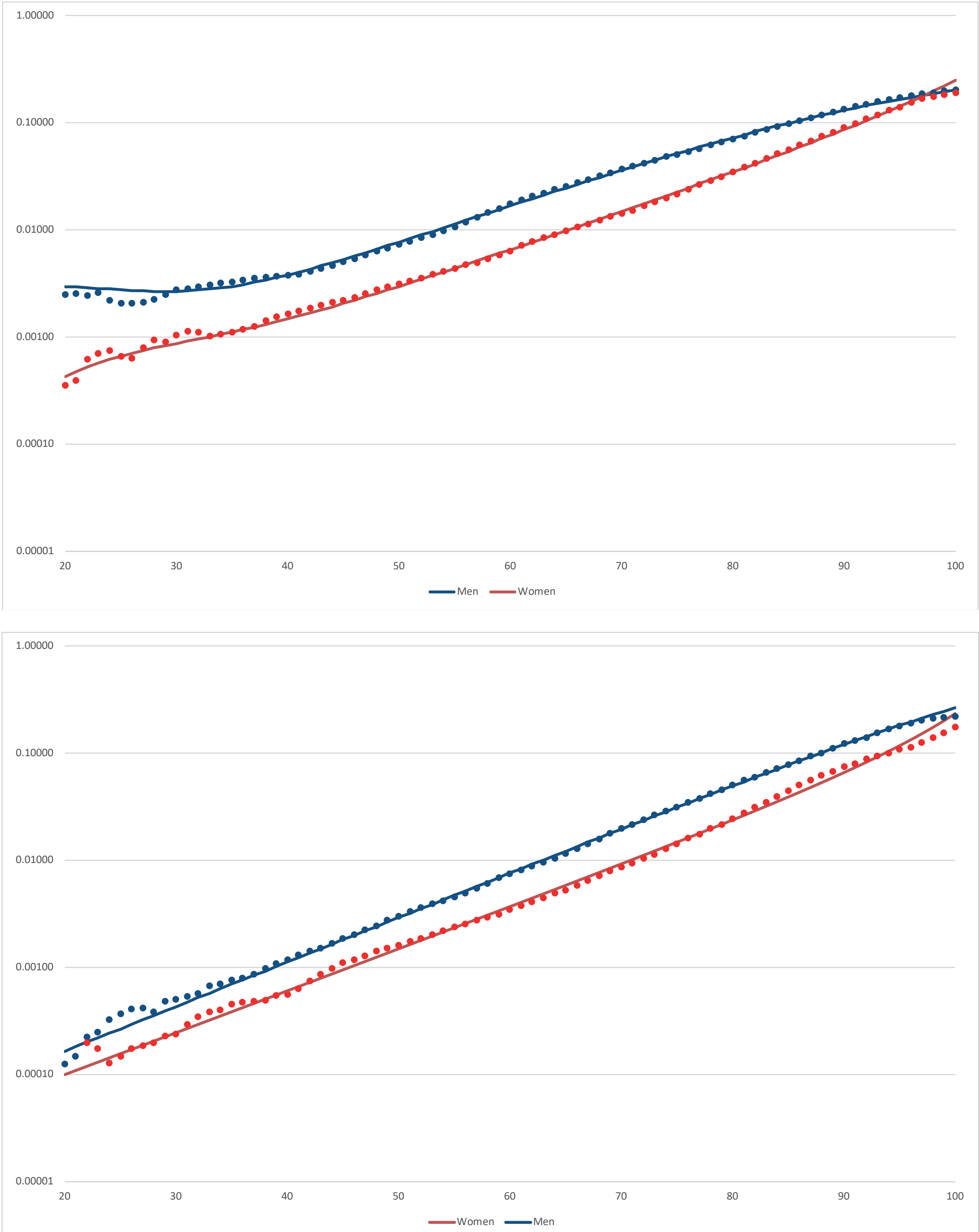

Figure 4 *Probability of death according to age, sex, and educational level – active and retired civil servants – 1994/2013*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

Similarly to what was observed for middle level men, the negative K parameter for the higher level indicates mortality with decelerating growth in the higher ages. In the same way as was observed for middle level women, the positive K parameter for those from the higher level indicates mortality with accelerating growth in the higher ages, visible even for the ages below 100.

The male over-mortality is greater for the middle level population and among the earlier ages, as expected. For the middle level population, the probability of male death is almost 7 times that for females at 20 years, falling with age until reaching the same level at 97. As for the higher level population, at 20 years, the over-mortality is a little below 2, rising slightly with age, reaching a maximum at 73 and falling after this age, with a cross-over at 80 years with the over-mortality of the middle level population.

The over-mortality for educational level (probabilities of the middle level in the numerator and of the higher level in the denominator) is greater for the male population and in the earlier ages, as expected. For the male population, the probability of death for the middle level is almost 18 times that of the higher level at 20 years, falling with age until reaching the same levels immediately after 90. This value, in the earlier ages, is mainly due to the different mortality from external causes, which is much greater for the population with the lower educational level. As for the female population, at 20 years, the over-mortality is a little above 4 (values for the middle level around four times the value for the higher level), falling with age and with a cross-over at 80 years with the over-mortality of the male population.

3.3 Comparison with Market Tables

This section presents the comparisons between the estimated tables for the whole period, 1993/2014, for the four combinations of sex and educational level, with selected tables used by the insurance market [for characteristics of these tables, see SOA (2017)]. These comparisons are made based on the probabilities of death and a figure of merit, the deviance, which summarizes the quality of the fit for all ages in one statistic.

Figure 5 and Figure 6 present for men and women, respectively, the comparison of the estimated mortalities for the 1993/2014 period (reference January 2004, middle of the period) for civil servants according to educational level, and some selected life tables used by the insurance market. For men in the youngest ages, the estimated values for the civil servants almost serve as an upper (middle level) and lower (higher level) limit for the mortalities presented in the market tables. The exceptions are the upwards IBGE tables and the downwards Commissioner's Standard Ordinary Tables (CSO, 2001). For women, the adjusted values appear in a much lower relative position.

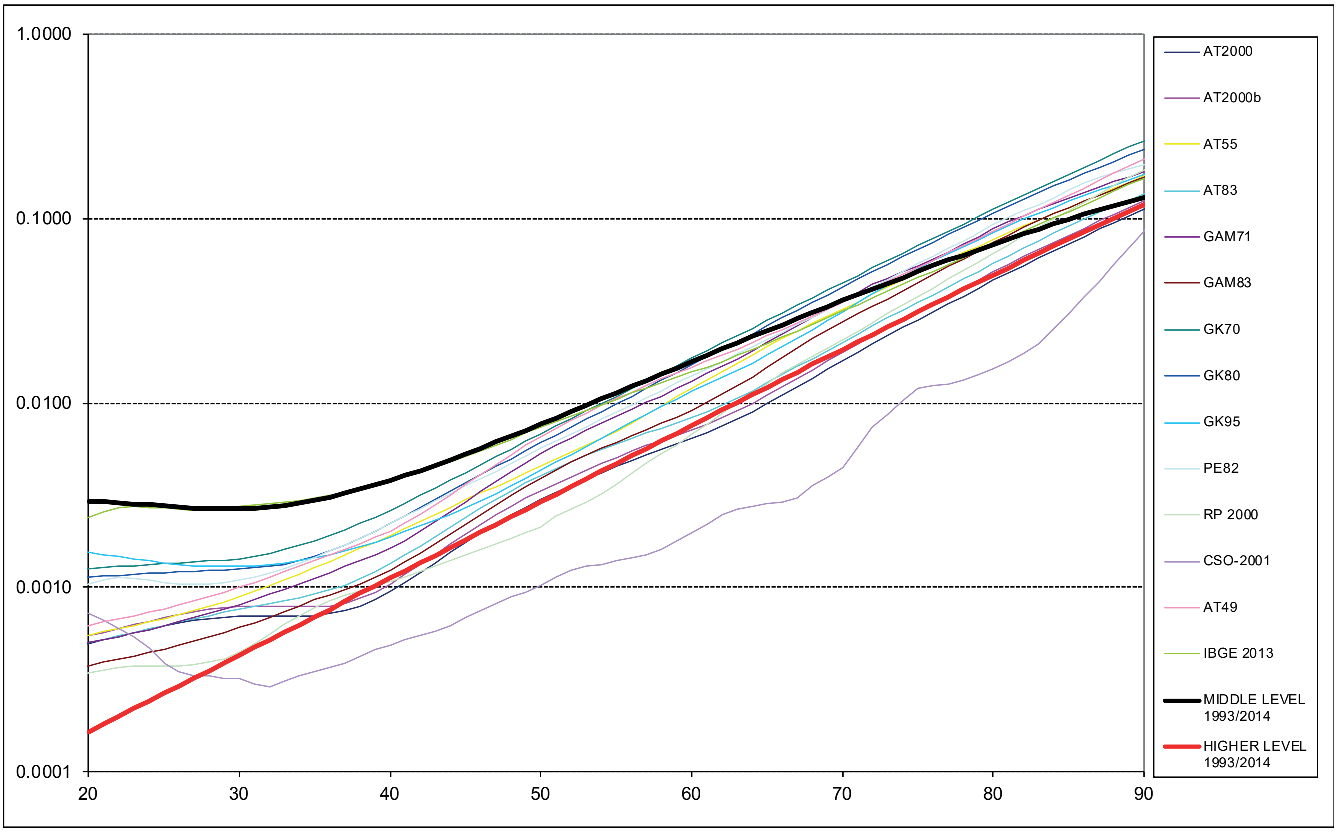

Figure 5 *Probability of death (log scale) – active and retired Executive branch federal civil servants according to educational level – men –1993/2014 – comparison of the adjusted values with market tables*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

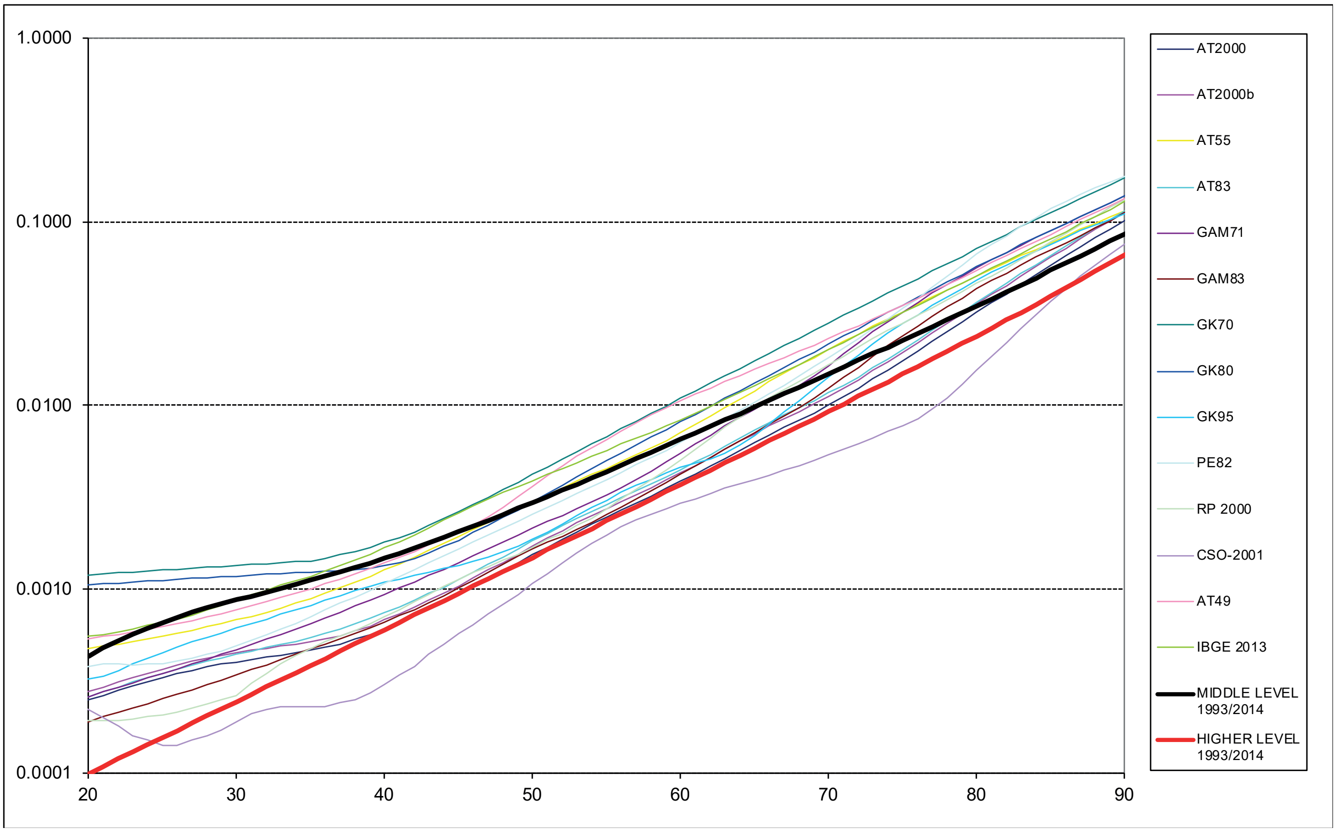

Figure 6 *Probability of death (log scale) – active and retired Executive branch federal civil servants according to educational level – women –1993/2014 – comparison of the adjusted values with market tables*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

As can be observed, the goodness of fit to the raw data of the different tables used by the market varies quite a lot with age and sex. It is worth remembering that the common practice in the case of private insurance companies is not to choose the table with the highest goodness of fit, but to use one established by the market, assuming a loading factor (corresponding to a unilateral confidence interval) or a lateral shift in age, to guarantee the solvency and profitability of the system. For closed private pensions, a loading can be used for plans with smaller contingents, due to the variance associated with the process. For public schemes with higher contingents of personnel, the variance can be absorbed by the system, but in a payout system an adequate choice enables a better evaluation of future spending, as well as better planning of personnel policy.

The use of figures of merit that summarize the goodness of fit of a dataset to a particular table (or set of tables) is common. In this text, the deviance (Croix, Planchet & Thérond, 2013; Dobson & Barnett, 2008) is used. It is defined as two times the difference between the log likelihood of the saturated model and that of the table being tested; that is, $D = 2(l[\hat{q}(.,s)] - l[q_{tb}(.,s)])$. In the saturated model, the probabilities for each age coincide with the crude probabilities, $\hat{q}$. This statistic has an asymptotic distribution χ^2 with the number of degrees of freedom being equal to that of the individual ages used and it is derived from the likelihood ratio test. In this text, the statistics for the interval of ages between 30 and 80 were considered.

The literature mentions other figures of merit, some also based on the vraisemblance function, such as the Wald and the Score tests. These and the deviance are asymptotically equivalent, converging towards the same distribution χ^2.

Considering that the distribution of deaths for a given age x and sex s follows, as already mentioned, a binomial distribution B $[N(x,s);q_{tb}(x,s)]$, in which $N(x,s)$ is the population at risk with age x and sex s, assuming a given table tb, with a specific probability of mortality $q_{tb}(x,s)$ and with $\tilde{o}$ being the vector of observed deaths, the likelihood of table Tb for a given sex s would be defined as:

$$f(\tilde{o}_s) = \prod_x \left\{ \binom{N(x,s)}{d(x,s)} [q_{tb}(x,s)]^{d(x,s)} [1 - q_{tb}(x,s)]^{N(x,s)-d(x,s)} \right\} \quad (8)$$

in which *d(x,s)* are the deaths occurring with age *x* and sex *s* and the corresponding log likelihood would be:

$$l[q_{tb}(.,s)] = \ln f(\tilde{o}_s) = \sum_x \left\{ \ln \binom{N(x,s)}{d(x,s)} + d(x,s)\ln[q_{tb}(x,s)] + (N(x,s) - d(x,s))\ln[1 - q_{tb}(x,s)] \right\} \quad (9)$$

The deviance would then be:

$$2(l[\hat{q}(.,s)] - l[q_{tb}(.,s)]) = \sum_x \left\{ d(x,s)\ln\left[\frac{\hat{q}(x,s)}{q_{tb}(x,s)}\right] + (N(x,s) - d(x,s))\ln\left[\frac{1-\hat{q}(x,s)}{1-q_{tb}(x,s)}\right] \right\} \quad (10)$$

Below, for each educational level, the graphics with the deviance values calculated for each combination of sex and table considered, are presented for analysis. The advantage of the deviance is that this figure of merit not only takes the statistical distribution of the data into account, but also the age profile of the population involved.

Figures 7 and 8 present the values for the deviances calculated for the 30- to 80-year-old age group for each sex, respectively, for the middle and higher level population of Executive branch civil servants. It is noted that in the case of this figure of merit, the search is for the table that minimizes the value. Both for middle and for higher level men, the table with the best goodness of fit, considering the deviance as a figure of merit, is the adjusted one and the worst is CSO-2001. In the case of higher level men, AT2000b is presented as a second alternative, with a deviance in the same order of magnitude of three times greater.

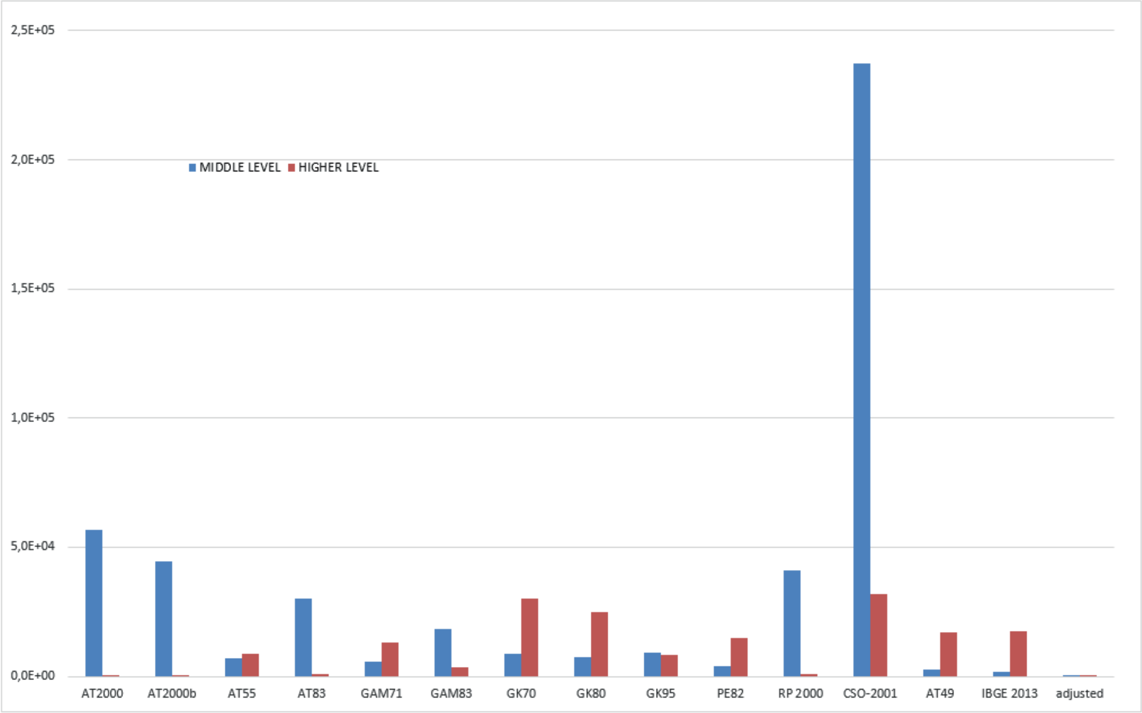

Figure 7 - *Deviance of the selected and adjusted tables in relation to the raw values observed – active and retired Executive branch federal civil servants according to educational level – men –1993/2014*

Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

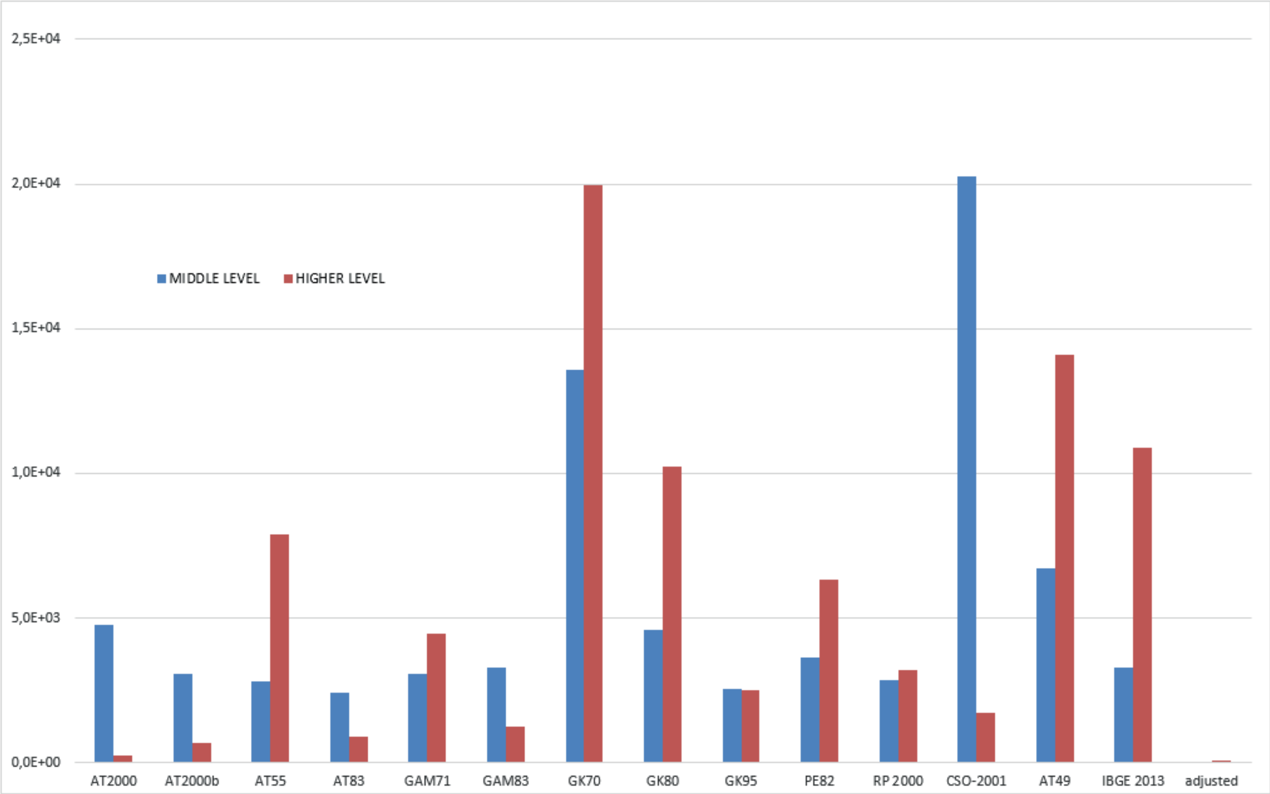

Figure 8 - *Deviance of the selected and adjusted tables in relation to the raw values observed – active and retired Executive branch federal civil servants according to educational level – women –1993/2014*
Source: *Elaborated by the authors using the data from the Integrated Human Resource Administration System (Siape).*

For the middle and higher level women, the tables with the best goodness of fit are the adjusted tables, the same identified for men. The table with the worst goodness of fit for the middle level is CSO-2001, and for the higher level it is GK70. For higher level women, table AT2000 is presented as a second option, with a deviance in the same order of magnitude as the adjusted table of five times greater.

4. FINAL REMARKS

This study confirms the expected behavior of the mortality ranks. In theory, both sexes of the Brazilian population should present higher values than those of civil servants, both middle level and higher level. It is observed that the mortalities of higher level civil servants were lower than those of middle level civil servants, both for men and for women. This appears to indicate that the socioeconomic conditions associated with educational level also affect mortality among Brazilian civil servants, confirming similar studies carried out in other countries. This gap in socioeconomic conditions, which also translates into a gap in mortality, is smaller among women.

As was expected, the values obtained for women were always lower than the values found for men. Continuity of the study to estimate probabilities of death in other time intervals would be ideal. The monitoring of specific populations could work as a sentinel-event for larger populations, possibly signaling the existence of trends, such as the bump in mortality among young adults of both sexes, notable even with the scarcity of points in time among the middle level civil servants of both sexes.

Probabilities of death for the population as a whole depend, on one hand, on the availability of information on deaths from the IBGE Civil Registry or from the Ministry of Health's Mortality Information System (SIM), which is not available in real time, as the administrative data of Siape is. On the other hand, they also depend on population information from the Census, which are usually collected at a ten-year time interval or from inter-census estimates. Probabilities calculated using the administrative records can be done in real time and with numerator and denominator information from the same source.

Moreover, specific life tables for a contingent of employees can be used to devise the institution's policies. It is possible, for example, to estimate future spending on retirements and pensions. It is also possible to plan a future hiring scheme based on the outflows from the body of employees (whether through death, retirement, or exoneration). It is also possible to devise awareness campaigns for preventable causes of a greater magnitude in the group, such as, probably, external causes, cardiovascular diseases, etc.

One possible extension of this study would be a modeling that considers the improvement in the probabilities of death and a measure of their temporal variation (Rosner et al., 2013). One option for this extension could be a modification of the model proposed by Lee and Carter (1992), considering the probabilities of the product of the model from Heligman and Pollard (1980) and a smooth deterministic function of age and time, instead of the random function, originally proposed by Lee and Carter.

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Annex - *Estimated values for the probabilities of death (q_x)*

Age	Middle level women	Middle level men	Higher level women	Higher level men
20	4.2851822E-04	2.9392781E-03	9.8993071E-05	1.6457956E-04
21	4.7554984E-04	2.9206961E-03	1.0834205E-04	1.8113487E-04
22	5.2256838E-04	2.8879381E-03	1.1857429E-04	1.9935519E-04
23	5.6902700E-04	2.8468176E-03	1.2977330E-04	2.1940792E-04
24	6.1457135E-04	2.8024574E-03	1.4203050E-04	2.4147725E-04
25	6.5904297E-04	2.7592656E-03	1.5544598E-04	2.6576590E-04
26	7.0246918E-04	2.7209667E-03	1.7012931E-04	2.9249693E-04
27	7.4504376E-04	2.6906640E-03	1.8620045E-04	3.2191578E-04
28	7.8710285E-04	2.6709203E-03	2.0379071E-04	3.5429255E-04
29	8.2909911E-04	2.6638434E-03	2.2304390E-04	3.8992445E-04
30	8.7157675E-04	2.6711714E-03	2.4411746E-04	4.2913848E-04
31	9.1514897E-04	2.6943529E-03	2.6718379E-04	4.7229446E-04
32	9.6047873E-04	2.7346194E-03	2.9243165E-04	5.1978829E-04
33	1.0082635E-03	2.7930500E-03	3.2006777E-04	5.7205555E-04
34	1.0592235E-03	2.8706270E-03	3.5031856E-04	6.2957545E-04
35	1.1140942E-03	2.9682842E-03	3.8343195E-04	6.9287521E-04
36	1.1736217E-03	3.0869482E-03	4.1967954E-04	7.6253483E-04
37	1.2385608E-03	3.2275727E-03	4.5935879E-04	8.3919235E-04
38	1.3096761E-03	3.3911687E-03	5.0279560E-04	9.2354960E-04
39	1.3877444E-03	3.5788291E-03	5.5034698E-04	1.0163786E-03
40	1.4735597E-03	3.7917507E-03	6.0240412E-04	1.1185284E-03
41	1.5679381E-03	4.0312528E-03	6.5939568E-04	1.2309328E-03
42	1.6717249E-03	4.2987938E-03	7.2179143E-04	1.3546188E-03
43	1.7858023E-03	4.5959862E-03	7.9010629E-04	1.4907158E-03
44	1.9110972E-03	4.9246100E-03	8.6490471E-04	1.6404653E-03
45	2.0485901E-03	5.2866255E-03	9.4680555E-04	1.8052325E-03
46	2.1993242E-03	5.6841857E-03	1.0364875E-03	1.9865182E-03
47	2.3644157E-03	6.1196479E-03	1.1346948E-03	2.1859719E-03
48	2.5450632E-03	6.5955849E-03	1.2422441E-03	2.4054065E-03
49	2.7425591E-03	7.1147971E-03	1.3600312E-03	2.6468142E-03
50	2.9583011E-03	7.6803229E-03	1.4890396E-03	2.9123839E-03
51	3.1938036E-03	8.2954507E-03	1.6303488E-03	3.2045199E-03
52	3.4507115E-03	8.9637291E-03	1.7851443E-03	3.5258630E-03
53	3.7308134E-03	9.6889782E-03	1.9547282E-03	3.8793130E-03
54	4.0360568E-03	1.0475299E-02	2.1405316E-03	4.2680533E-03
55	4.3685644E-03	1.1327086E-02	2.3441277E-03	4.6955777E-03
56	4.7306514E-03	1.2249030E-02	2.5672464E-03	5.1657197E-03
57	5.1248448E-03	1.3246131E-02	2.8117912E-03	5.6826842E-03
58	5.5539049E-03	1.4323705E-02	3.0798575E-03	6.2510817E-03
59	6.0208479E-03	1.5487382E-02	3.3737531E-03	6.8759658E-03
60	6.5289722E-03	1.6743112E-02	3.6960216E-03	7.5628733E-03
61	7.0818860E-03	1.8097166E-02	4.0494676E-03	8.3178677E-03
62	7.6835399E-03	1.9556124E-02	4.4371865E-03	9.1475857E-03
63	8.3382611E-03	2.1126872E-02	4.8625969E-03	1.0059288E-02
64	9.0507933E-03	2.2816584E-02	5.3294773E-03	1.1060911E-02
65	9.8263404E-03	2.4632705E-02	5.8420085E-03	1.2161128E-02
66	1.0670616E-02	2.6582921E-02	6.4048205E-03	1.3369404E-02
67	1.1589898E-02	2.8675128E-02	7.0230468E-03	1.4696068E-02
68	1.2591094E-02	3.0917387E-02	7.7023856E-03	1.6152373E-02
69	1.3681808E-02	3.3317872E-02	8.4491708E-03	1.7750572E-02
70	1.4870426E-02	3.5884811E-02	9.2704523E-03	1.9503988E-02
71	1.6166203E-02	3.8626410E-02	1.0174090E-02	2.1427092E-02
72	1.7579370E-02	4.1550772E-02	1.1168860E-02	2.3535582E-02
73	1.9121254E-02	4.4665798E-02	1.2264583E-02	2.5846458E-02
74	2.0804416E-02	4.7979081E-02	1.3472268E-02	2.8378098E-02
75	2.2642810E-02	5.1497787E-02	1.4804281E-02	3.1150339E-02
76	2.4651966E-02	5.5228523E-02	1.6274553E-02	3.4184541E-02

Annex - *Cont.*

Age	Middle level women	Middle level men	Higher level women	Higher level men
77	2.6849207E-02	5.9177198E-02	1.7898812E-02	3.7503657E-02
78	2.9253897E-02	6.3348871E-02	1.9694869E-02	4.1132287E-02
79	3.1887737E-02	6.7747597E-02	2.1682954E-02	4.5096721E-02
80	3.4775110E-02	7.2376263E-02	2.3886125E-02	4.9424966E-02
81	3.7943488E-02	7.7236433E-02	2.6330760E-02	5.4146754E-02
82	4.1423928E-02	8.2328189E-02	2.9047152E-02	5.9293521E-02
83	4.5251646E-02	8.7649978E-02	3.2070249E-02	6.4898356E-02
84	4.9466731E-02	9.3198480E-02	3.5440559E-02	7.0995917E-02
85	5.4114986E-02	9.8968491E-02	3.9205280E-02	7.7622293E-02
86	5.9248978E-02	1.0495282E-01	4.3419721E-02	8.4814821E-02
87	6.4929303E-02	1.1114225E-01	4.8149103E-02	9.2611843E-02
88	7.1226173E-02	1.1752546E-01	5.3470861E-02	1.0105239E-01
89	7.8221377E-02	1.2408908E-01	5.9477637E-02	1.1017581E-01
90	8.6010761E-02	1.3081771E-01	6.6281180E-02	1.2002128E-01
91	9.4138035E-02	1.4062523E-01	7.3502933E-02	1.2911442E-01
92	1.0279240E-01	1.5086262E-01	8.1347383E-02	1.3874105E-01
93	1.1197774E-01	1.6151327E-01	8.9845480E-02	1.4890728E-01
94	1.2169681E-01	1.7256011E-01	9.9025870E-02	1.5961481E-01
95	1.3194931E-01	1.8398292E-01	1.0891408E-01	1.7086029E-01
96	1.4273184E-01	1.9575858E-01	1.1953166E-01	1.8263460E-01
97	1.5403795E-01	2.0786134E-01	1.3089523E-01	1.9492226E-01
98	1.6585823E-01	2.2026312E-01	1.4301553E-01	2.0770075E-01
99	1.7818041E-01	2.3293389E-01	1.5589646E-01	2.2094004E-01
100	1.9098964E-01	2.4584214E-01	1.6953414E-01	2.3460215E-01
101	2.0426869E-01	2.5895524E-01	1.8391600E-01	2.4864086E-01
102	2.1799831E-01	2.7223997E-01	1.9902003E-01	2.6300167E-01
103	2.3215747E-01	2.8566292E-01	2.1481417E-01	2.7762185E-01
104	2.4672381E-01	2.9919095E-01	2.3125585E-01	2.9243081E-01
105	2.6167394E-01	3.1279161E-01	2.4829182E-01	3.0735068E-01
106	2.7698383E-01	3.2643351E-01	2.6585821E-01	3.2229715E-01
107	2.9262916E-01	3.4008666E-01	2.8388088E-01	3.3718057E-01
108	3.0858566E-01	3.5372280E-01	3.0227615E-01	3.5190726E-01
109	3.2482941E-01	3.6731555E-01	3.2095173E-01	3.6638099E-01
110	3.4133713E-01	3.8084068E-01	3.3980799E-01	3.8050472E-01
111	3.5808643E-01	3.9427621E-01	3.5873953E-01	3.9418227E-01
112	3.7505602E-01	4.0760247E-01	3.7763687E-01	4.0732016E-01
113	3.9222583E-01	4.2080216E-01	3.9638832E-01	4.1982931E-01
114	4.0957723E-01	4.3386031E-01	4.1488196E-01	4.3162673E-01
115	4.2709303E-01	4.4676426E-01	4.3300753E-01	4.4263691E-01
116	4.4475758E-01	4.5950355E-01	4.5065839E-01	4.5279311E-01
117	4.6255681E-01	4.7206983E-01	4.6773313E-01	4.6203830E-01
118	4.8047819E-01	4.8445673E-01	4.8413719E-01	4.7032585E-01
119	4.9851072E-01	4.9665968E-01	4.9978406E-01	4.7761988E-01
120	1.0000000E+00	1.0000000E+00	1.0000000E+00	1.0000000E+00

Source: *Elaborated by the authors using data from the Integrated Human Resource Administration System*