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Analysis of Allocations of Brazil's Closed Pension Funds

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Abstract

Research Problem: What are the characteristics of the allocations in the respective investment assets (investment portfolios) of the closed pension funds in Brazil about risk *x* return? **Motivation:** This article aimed to deepen the knowledge of the social security systems segment, mainly the Closed Complementary Pension Entities (EFPC, which is also known in Brazil as Pension Funds) by way of national and international literature review, but they had their power maximized by making the Investment Statements—Assets database available to all closed entities (from 2010 to 2017), through the Regulatory Agency. **Test Hypotheses:** To achieve the objective of this study, we proposed two hypotheses: 1) allocations to higher/lower risk assets generate higher/lower risk, and 2) allocations to higher/lower risk assets generate higher/lower returns. Notably, the referred research hypotheses are not statistical hypotheses identified in the samples and need to be tested as valid in a population because this study analyzes the population of the Investment Statements—Assets (IS) of the closed pension funds of Brazil, with no hypothesis testing. **Adopted Methodology and Analyses:** It used panel data modeling and Generalized Method of Moments (GMM-Arellano-Bond), about the population of the Investment Statements—Assets (IS) of these entities, made available by the Regulatory Agency. It was analyzed together, by modalities of Defined Benefit (DB), Defined Contribution (DC), and Variable Contribution (VC) plans and by size (small, medium, and large). This paper was to research allocations from investment assets (investment portfolios period 2010-2017), from pension funds (2nd pillar) of the Brazilian system. **Findings:** Suggest that closed pension funds are efficient (Sharpe), and when considering the model applied and the annual periodicity, the allocations in higher-risk investments result in a higher return.

Keywords

Brazilian Pension Fund, Risk and Return, Institutional Investors, Financial

Service, Generalized Method of Moments (GMM)

1. Introduction

The studies of social security systems of a global character have increased, and the life expectancy of the population has also increased, which was corroborated in the bibliographic review conducted in this study and is presented in the body of the work. That today's human beings live longer and better raises challenges regarding social protection and income guarantee systems after individuals' working years, that is, where will the resources come from to guarantee the income levels of the world's population? These resources will be either public or private, society will have funded or capitalized pension systems.

Understanding the purposes and aims of a social security entity is not always an easy task, the comparison of pension funds with corporations can bring a better understanding of this industry. Cunha Júnior (2013) presented a comparative Chart 1 that was adapted by the author.

The motivation for this research is a long period dedicated to the study of complementary social security, and it contributes to the realization of this work; however, the main factor is the availability of the database with all the Closed Complementary Pension Entities (EFPC) Investment Statements—Assets (IS) recognized in the Brazilian market as pension funds, through the special authority responsible for regulating the industry in Brazil.

The Investment Statements—Assets (IS) are available with information on the set of allocations made by the 297 pension funds and their 1098 benefit plans (numbers in September 2018—population of all funds, plans, and investments), from the 1st quarter of 2010 to the 4th quarter of 2017, and enable the study to be conducted by comparing the historical series of investments and the explanatory variables (benchmarking) and control.

We analyze the closed private pension industry as a whole because we work with the investment population of that industry and because of the distinction between the types of benefit plans—Defined Benefit (DB), Defined Contribution

Chart 1. Differences between EFPC/pension fund and corporations.

Compared Items	EFPC/Pension Funds	Corporation and Incorporated
Goal	Benefits to Participants	Profit
Legal Nature	Foundations	Open or Closed Society
Members' Rights	Right to Benefits and/or Pensions	Quotas/Shares/Management
Operating Cycle	Very Long Term	Short/Medium Term
Financial Flow	Accumulate Funds for Future Disbursements	Distributes Profit to Each Cycle

Source: Cunha Júnior (2013). Adapted by the authors.

(DC), and Variable Contribution (VC)—and their size (small, medium, and large), the particularities that configure the originality of the studies in this area.

The article is organized as follows: in this Introduction where the theme is presented, its peculiarities and what were the motivations, the specific distinctions of the study and its hypotheses. The Literature Review describes, initially, some foundations of relevant concepts addressed, and later, the entire process of the extensive research carried out, historically contextualizing the studies of social security systems in Brazil and in the World, the most discussed subjects and the future directions that are being taken. The Methodology presents how information on pension fund allocations was handled, with the purpose of comparing each set of investments with market benchmarking. The Analysis of Results discusses the evolution of investment returns and risk between 2010 and 2017, compared to market benchmarks and returns. Ending with the Conclusion, where the main contributions of the work and the main lines of future research and works that can be developed are addressed.

2. Literature Review

National and international research, because of the wide range of topics available, should consider the specificity of social security studies and the absence of symmetry between pension systems and social security worldwide, which although may seem similar, are invariably at different stages, requiring different allocation strategies, in addition to the personal matter of each private pension investor.

Among the international works, Marples (1947), through the development of some mathematical formulas, investigated the financial situation of pension funds in the United Kingdom (UK), namely, the calculations of benefits and contributions of a standard fund, but was unable to generalize the results to all the funds, depending on the differences in the payment flows of these entities. Trowbridge (1952) presented an important work on the methods of financing pension funds, terminology that he adopted to describe what benefits should be subject to financing, a broad discussion with the authors of the subject, the United States (US) Treasury "rules as to the maximum contribution for which full tax deduction can be claimed".

When analyzing the preponderance of the financial management of pension funds, namely, asset allocation and control of future contribution flows, Boulier et al. (1995) performed simulations of funds from France, the United States, and Japan and indicated that they did not consider the risk aversion of the portfolios, besides reporting difficulties with the actual calculations, which prevented them from reaching a general solution. In the same line of study, Cairns and Parker (1997) presented work on the variability of the amortization period of contributions, levels of financing, and contribution rates of DB pension plans and used the concept of efficient frontier for this purpose: to obtain an optimal financing strategy. The premise of this study was the dependent rate of return and the level

of invariant financing (ergodic).

In another line of study, Gollier (2008) proposed a simplified model of a collective pension plan and analyzed the management of portfolios, disbursements of benefits to retirees, and the strategy of receiving dividends by shareholders by using the utility function. Von Neumann-Morgenstern of two agents and, in the end, estimated the sharing of generational risk. Additionally, by following differentiated research, Hoevenaars et al. (2008) studied asset allocation strategies (e.g. stocks, listed properties, commodities, hedge funds, local government, and corporate and treasury bonds) of agents who had liabilities influenced by inflation and real interest rates (e.g. the solution simulated a hypothetical model) and measured the correlations in the short and long terms by exploring the covariance between assets and value-at-risk estimates; they also conducted vector autoregression for returns, liabilities, and the treatment of macroeconomic variables. They observed investing in the long term, the addition of hedge liabilities, and the generation of greater benefits.

Through the use of an exclusive database, from CEM Benchmarking Inc., Aglietta et al. (2012) analyzed the asset allocation of US pension funds from 1990 to 2008; they referred to DB plans and found through panel regressions that they actively managed the portfolios of these funds (a practice found in less than 4% of the total sample) and could add more return compared to the passive allocation from investment policies; they confirmed the relevance of active management as a source of performance within each asset class, the main result of the study.

In a comparative study of performance between US and European pension funds from 2002 to 2013, Foo and Witkowska (2016: p. 97) as follows:

> It is not easy to find common metrics to assess the performance of pension funds, including, subsidizing the decision of individual investors to make their allocations, and this fact has aroused discussions both in academia and among managers in the social security segment, also affecting the political environment, concerned with the solvency of social security systems.

More recently, Broeders et al. (2019) analyzed the return versus performance ratio of 218 Dutch professional pension funds from 2012 to 2017 by using a cross-regression model; among other findings, they found that excess returns on specialized funds are restricted to hedge funds, and there is also an advantage in size when larger funds also produce excess returns compared to those of individual asset classes.

Among the research on the Brazilian market, Rabelo (1998), in a qualitative study, presented an overview of the first 20 years of the Brazilian complementary pension system and discussed its importance as development funding, capital market promotion, and decentralization of corporate control. With the perspective of analyzing the variable income of pension funds as a productive investment, Amaral et al. (2004) used the capital asset pricing model and concluded

that the measured performance is invariably higher than expected and that larger entities have a better performance than smaller entities. By contrast, Rieche (2005) discussed the best practices for controlling the various risks that pension funds are subject to (e.g. market, credit, operational, liquidity, and mismatch between assets or liabilities), posing a counterpoint between Brazilian legislation and that of the countries in the Organization for Economic Co-operation and Development (OECD). Pinheiro et al. (2005) also used qualitative analysis and analyzed the investment regulation guidelines of the pension funds, which from 1978 to 1994 stipulated minimum and maximum limits, and from there only maximum limits, and concluded that there was a need to adapt the legislation to the need to diversify investments in the search for better returns, because of the concentration of fixed income funds' portfolios.

Close to the focus of this research, Baima and da Costa Jr. (2010) proposed a benchmark portfolio called the "Pension Funds Index" after analyzing secondary data from the segment association, from 1998 to 2006, in addition to risk metrics, Jensen's alpha, and the Treynor and Sharpe indices. They found that the use of the IBovespa (São Paulo Stock Exchange Index) and the SELIC (Special Settlement and Custody System—Basic Interest Rate in Brazil—considered Risk Free) rate as benchmarking in the sample period could distort the performance of the funds' investments, but in general, the performance of these entities, considering the "Pension Funds Index" and IBovespa, was satisfactory and in line with the risk and diversification of the industry.

In another study on benchmarking, Bicalho (2018) analyzed the performance of pension funds, distinguishing between public and private sponsorships, by using the quarterly data from the accounting balance sheets released by the Regulatory Agency (from 2010 to 2015), which was managed by the author to structure profitability. This author studied the entities' total profitability and variable income returns by using references such as Interbank Deposit Certificates, SELIC, IBovespa, Broad Consumer Price Index, and the exchange rate variation, by using linear regressions and the dynamic panel in the Arellano-Bond approach, confirming the results that were expected for Brazilian pension funds and verifying the interference of the country's internal crisis in the performance of the variable income segment.

However, in the case of studies in Brazil that have comprehensively investigated the database of pension funds in that market, no studies have considered the population of these entities, generally used secondary data, extracted information from the financial statements, or used hypothetical models.

According to our review of the literature, national and international studies have attempted to analyze interrelationships in pension plans in samples but have not shown the allocation of investments to mitigate risk and leverage returns.

All of the cited research has detailed the studies of pension funds without analyzing the core of the performance metrics of the risk versus return relation-

ships.

Thus, the studies in our literature review have

- no descriptive treatment of the allocations of the closed pension fund investment assets (investment portfolios),
- no analysis of the universe of these funds, and
- no diagnosis of the risk versus return ratio based on the allocations made in the portfolios.

Therefore, based on these findings, the objective of this article is to analyze and diagnose the characteristics of the allocations made in investment assets (investment portfolios) in closed pension funds in Brazil, from 2010 to 2017, to build an econometric model to assess the risk versus return ratio in the respective allocations of those funds.

3. Methodology

3.1. Sample

The database was made available by the Regulatory Agency of the closed private pension segment in Brazil, in the case of Investment Statements—Assets (IS) with the set of information on the allocations made by the 297 pension funds and their 1098 benefit plans, and numbers of September 2018; therefore, the population of all funds, plans, and investments from the 1st quarter of 2010 to the 4th quarter of 2017 led to the realization of the study that compares the historical series of investments and some benchmarks (considered proxies), the average return of the investment segments, and the risk of the portfolio, among the other correlations, analyzed.

The database consisted of spreadsheets with columns of information and fields, which served as a subsidy for the choice of assets to be considered in the analyses, in addition to providing a random numerical identification of each benefit plan, attributed by the Regulatory Agency, the total guarantee reserves of each fund and other information. The base contained the reference year and month, a sequential number attributed to the EFPC, a sequential number attributed to the benefit plan, the International Securities Identification Number shares and asset fund, type of share fund, active fund and multimarket structured segment shareholder, type of asset, name of the active issuer, CNPJ (National Register of Legal Entities) number of the active issuer, type of active fund, active name, active maturity date, number of assets weighted by the percentage of participation, total value weighted by the percentage of participation, investment segment according to CMN Resolution (National Monetary Council), convertible debenture, profit-sharing debenture, Specific Purpose Society (SPE) debenture, property sold in installments, and value of the plan's guarantee resource.

To proceed with analysis by type of DB pension plan, DC, and VC, this classification was also made available by the Regulatory Agency.

3.2. Estimation Model and Method

In this article, we grouped the database assets into five segments, according to similarity and characteristics:

1) Stocks Segment comprises the subsection: Stocks, Future, Options, Swap, and Term.

2) Funds Segment—Fixed Income with the subsection: Fund Shares, Deposit, Credit Right, and Loan.

3) Real Estate Segment with the subsection: Real Estate and Real Estate Financing.

4) Private Securities Segment with the subsection: Private Securities, Committed Operation, and SPE.

5) Public Bonds Segment: only with the Public Bonds subsection.

Two other classifications were included for purposes of risk and return analysis of the investment portfolio compositions of the Pension Fund plans, also by quarter:

I) By type of pension plan, as established in the current legislation:

- **Classification 1**—DB Plans.
- **Classification 2**—DC Plans.
- **Classification 3**—VC Plans.

II) By size, according to a scale arbitrated by the authors, without reference to legislation or scientific work (in Brazilian currency-real):

- **Size 1**—Small-scale Closed Pension Benefit Plans: from R$1.00 to R$99,999.99.
- **Size 2**—Medium-sized Closed Pension Plans: from R$100,000.00 to R$999,999,999.99.
- **Size 3**—Large Closed Social Security Benefit Plans: above R$1,000,000,000.00.

With the use of classifications by type size, in addition to the survey of the formation of the respective portfolios, considering the total structuring, that is, the combined sum of all the plans of the pension funds, the possibility of comparison and analysis between the industry as a whole and the respective modalities and sizes of the plans, in addition to identifying relationships between closed pension plans DB, DC, and VC and between small, medium, and large sizes.

To achieve this objective, we proposed two hypotheses:

- Hypothesis 1: Allocations to higher/lower risk assets generate higher/lower risk.
- Hypothesis 2: Allocations to higher/lower risk assets generate higher/lower returns.

Notably, the referred research hypotheses are not statistical hypotheses identified in the samples and need to be tested as valid in a population because this study analyzes the population of the Investment Statements—Assets (IS) of the closed pension funds of Brazil, with no hypothesis testing.

Notably, we did not intend to develop a predictive econometric model of the performance of the investment portfolio, both individual by plan/fund, and of the population as a whole because each closed pension plan has its particulari-

ties; their individual allocation according to the duration calculation (i.e. time horizon in which social security benefits will be paid); and factors that influence, in a predominant manner, the asset allocation and the short- and long-term investment policy of these entities.

Even in the last century, authors had envisioned the uniqueness of pension benefit plans. According to Gray (1929: p. 280), when warning entrepreneurs interested in instituting pension plans for their employees, he concluded: "Without focusing on any degree of precision and depth—it is correctly emphasized that two funds cannot be treated as identical".

Other authors can be mentioned when referring to the difficulty of modeling optimal portfolios for pension benefit plans, or even econometric modeling. Sharpe (1976: p. 184) in a scientific article on the impacts of the Law of 1974—Employee Retirement Income Security (ERISA), a federal law that regulated the minimum standards of the North American private-sector retirement and health plans, emphasized that a large part of the diagnoses of the industry's pension started from the premise that the stakeholders (e.g. market, shareholders, employees, insurance companies) "were rational and would have access to the capital market" and concluded:

As usual in such conditions, corporate policy decisions do not matter, i.e. there is no single optimal funding policy. While this is not particularly surprising, it is instructive to see just how it comes about. The relevance of the results to the "real world" is of course another matter (Sharpe, 1976: p. 184).

Using this same argument, Gollier (2008: p. 1483) used a model with two agents in the same utility function as von Neumann-Morgenstern and summarized his main results while attempting to provide a realistic estimate of the gains of good to be part of the sharing of risks between generations, and he stressed, "...however, to make the model manageable, we made several simplifications compared to the real pension schemes".

Regarding further research, Zhang (2014: pp. 6-7) suggested focusing on the selection of portfolios in continuous time by using the modeling of mean-variance and emphasized that the ideal way to find generalist situations, with the assumption that "the risky asset follows models of elasticity of constant variance introducing different models of stochastic interest rates"; however, in the end, the reality of the facts was rendered, "It is noteworthy in the Scientific World Journal that the ideal solver with a generalized situation is very difficult".

Because of the literature considerations presented and the set of factors, assumptions, and classifications listed, the list of dependent, explanatory, and control variables was defined, enabling us to measure whether or not there were relations between them during the analysis period, which comprised the 1st quarter of 2010 until the 4th quarter of 2017. These variables were described and contextualized in **Chart 2**.

The list of explanatory variables does not include the "Real Estate Segment" with the subsection "Real Estate and Real Estate Financing", which were excluded

Chart 2. List of dependent and independent variables, their origins, and database .

Variables—Dependent (D), Explanatory (E) and Control (C)	Origin or Database
Risk (D)	Defined by the authors to measure relationships
Sharpe (D)	Defined by the authors to measure relationships
Stock Investments (E)	The segment of Stocks of the IS base of the Regulatory Agency with the subsection: Stocks, Future, Options, Swap, and Term—% of the allocation
Public Bonds (E)	Segment Public Bonds of the IS base of the Regulatory Agency with subsection: Public Bonds—% of the allocation
Private Securities (E)	Private Securities Segment of the IS base of the Regulatory Agency with subsection: Private Securities, committed operation, and SPE—% allocation
Funds Segment—Fixed Income (E)	The segment of Funds—fixed income of the IS base of the Regulatory Agency with subsection: Fund Shares, Deposit, Credit Right and Loan—% allocation
Accumulated Savings (C)*	IPEA Data (2020) (Institute of Applied Economic Research date)
Accumulated GDP (C)*	IBGE (Brazilian Institute of Geography and Statistics, 2020)
Accumulated SELIC (C)*	BACEN (Brazilian Central Bank, 2020)
Accumulated IPCA (C)*	IBGE

Source: Elaborated by the authors. *Values accumulated quarterly in symmetry with data from the Regulatory Agency Investment Statements—Assets (IS) database.

from the analysis because Stata® underperformed when the database of variables had a perfect linear relationship. We excluded this group of investments because it is considered less expressive concerning guarantee reserves, and part of the dynamics of its return is linked to legal regulations and not due to market pricing. Loan and financing operations included in the "Real Estate Segment", granted to participants in closed pension plans, often occur as reciprocity and an additional benefit, and the return required in these cases is basically to cover operating costs and the actuarial goal.

The complexity of the data to be analyzed includes that the database constitutes the population of the Investment Statements—Assets (IS) of closed pension benefit plans (the entire closed pension fund industry), and the set of dependent, explanatory, and control variables, which can be self-correlated, led to the option of processing information in the form of panel data.

The study approach we used was to analyze these entities (EFPC) together by using the modalities of the DB, DC, and VC plans, in addition to a classification arbitrated by the authors (small, medium, and large). We used data modeling in random-effects panels and those of the Generalized Method of Moments (GMM)—Arellano-Bond, considering as dependent variables Risk and Sharpe.

National and international studies of the Pension Fund industry, using panel data, are rare, and in the case of the GMM method, they are practically nonexistent; this finding was also corroborated by Bicalho (2018: p. 13) in a study conducted on the balance sheets of the Brazilian pension funds: "As much as many of the articles that study pension funds in the world use panel data, including those already mentioned in this work, no articles were found that work with the data through the dynamic panel model".

In a 2020 publication on open and closed complementary pensions, Nese and Giambiagi (2020) used the GMM model to verify whether corporate governance practices indicated a greater performance of closed funds, having reported the treatment of endogeneity problems present in studies of the cause and effect of the decision-making processes of managers, and realized that good corporate governance practices can be associated with improved investment performance; however, when the government or financial institution sponsorship occurs, eventual "conflicts of interest" will probably occur, contributing to minimize the performance of the allocations of these entities.

In the specific case of this study, in addition to the choice of panel data analysis, because of the behavior of population elements and variables, the simple regression panel model was used; next, the panel was rotated with Random Effects (REs). This type was used to the detriment of the panel with Fixed Effects (FEs) because the FE was more appropriate to analyze variables individually. The option of these panels was for both dependent variables: Risk and Sharpe.

In a literature review, Marques (2000: p. 9) referred to FE and emphasized, "We have in mind models whose coefficients may vary from individual to individual or in time, even though they remain as fixed constants, therefore, they do not random".

According to Fávero (2013: p. 134), "The advantage of the random effects model is that it estimates all the coefficients, even of the time-invariant regressors, and, therefore, the marginal effects".

The data models were considered in a panel of RE for the dependent variables Risk and Sharpe in the formula assumed as (y):

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \beta_3 x_{it3} + \beta_4 x_{it4} + \cdots + \beta_w x_{itw} + \mu_i + \varepsilon_{it} \quad (1)$$

where:

$t = 1, 2, 3, \ldots, T$ (time-lapse) and also, $i = 1, 2, 3, \ldots, n$ (cross-section lapse), considering that y is the dependent variable, x is the explanatory variable (w), and μ_i are the RE and not susceptible to the effects of time ε_{it}.

To calculate the Expected Return ($R_{\text{portfolio}}$) and Portfolio Risk ($S_{\text{portfolio}}$), the following expressions were used:

$$R_{\text{portfolio}} = \sum_{i=1}^{n} W_i \times R_i \quad (2)$$

$$S_{\text{portfolio}} = \sqrt{\left[W_1 \cdots W_n\right] \times \begin{bmatrix} \text{covar}_{11} & \cdots & \text{covar}_{1n} \\ \vdots & \ddots & \vdots \\ \text{covar}_{n1} & \cdots & \text{covar}_{nn} \end{bmatrix} \times \begin{bmatrix} W_1 \\ \vdots \\ W_n \end{bmatrix}} \quad (3)$$

where:

W_i = percentage of asset allocation (i);

R_i = return on the asset benchmark (i);

$\text{Covar}_{i,n}$ = covariance between benchmarks in the analysis period.

Concerning Sharpe, it was calculated by considering the Sharpe Index, which is the other dependent variable.

$$\text{Sharpe Index} = \frac{\left(R_{\text{portfolio}} - Rf\right)}{S_{\text{portfolio}}} \tag{4}$$

where:

$R_{\text{portfolio}}$ = Return on Portfolio;

Rf = Risk-Free Return;

$S_{\text{portfolio}}$ = Portfolio Risk.

For data analysis, the adequacy tests of the proposed models were elaborated. The assumptions of the models with emphasis on the evaluation of the presence of data heteroscedasticity, multicollinearity, and serial autocorrelation were evaluated. In addition, tests were applied to verify the adequacy of panel data in fixed and RE.

Specifically, the tests performed were as follows: an evaluation of the results of the heteroscedasticity tests (Wald test) and serial autocorrelation (Wooldridge test), and the Robust Hausman and Chow tests were used in the choice of the analysis methodology of the panel used. The tests presented are widely used in accounting and finance research and assist in deciding the methodology used to analyze the results. To control multicollinearity, correlation matrix analysis and the variance inflation factor test were used.

In the literature, we found few studies that had used a method similar to the method used in this study, making it impossible to indicate the signs observed in the explanatory variables Investments in Stock, Public Bonds, Private Securities, and Funds Segment—Fixed Income, with the dependent variables Risk and Sharpe.

In the case of studies of pension funds in other countries, Aglietta et al. (2012) showed no signs in their results of the panel data; there is only the comparison of performance with market benchmarks. Petraki and Zalewska (2017: p. 173) analyzed the performance of stock funds created in 2008 and 2009 (during the US sub-prime crisis) and found that they "performed well in the recovery of stock markets, and their R-T-bill (excess return on UK T-bills government bonds) and Sharpe index estimates were positive and statistically significant". The authors stressed, however, that they did not consider the individual performance of the assets that compose the funds, only the total of the fund concerning the benchmarking.

In the absence of literature on the relationship of expected signals, which compose the assets of pension funds, we used the basic concepts of finance; according to Assaf Neto (2014: p. 215), the capital market line presents the rela-

tionship between risk and return versus the most varied types of investments in the financial market because "the slope of the line indicates the remuneration (premium) required by the market for each risk unit presented by the asset, and higher returns can only be offered by higher-risk securities". Assaf Neto (2014: p. 215) also added: "The securities with the lowest risk (and also the lowest return) are those issued by the public, some of which are perceived by the market as risk-free". In the opposite sense, he found: "The riskiest assets are stocks and venture capital for investment". The slope of the line is positive, the higher the expected return in a linear relationship, the greater the expected risk. At the bottom end of the line is government bonds, and at the end of the line is the risk capital (direct operations in companies, e.g. as Venture Capital—Private Equity—allocation in Startups/Fintechs).

Therefore, following the foundations of the finance literature, the expected signs for the explanatory variables of this study, which can compose the investment portfolios of all closed pension benefit plans, are described in Chart 3.

4. Analysis of Results

The validity of Hypothesis 1 was verified: Allocations in higher/lower risk assets generate higher/lower risk when the results of the econometric model are analyzed,

Chart 3. Expected signal for the dependent variables.

Variables—Dependent (D), Explanatory (E)	Expected Signal about the Dependent Variable
Risk (D)	
Stock Investments (E)	Positive (+) for the stocks segment (stocks, futures, options, swap, and term)
Public Bonds (E)	Negative (–) for the public bonds segment (only this subsection)
Private Securities (E)	Negative (–) for the private securities segment (private securities, committed operation, and SPE)
Funds Segment—Fixed Income (E)	Negative (–) for the fixed income funds segment (Fund shares, deposit, credit rights, and loan)
Sharpe (D)	
Stock Investments (E)	Positive (+) for the stocks segment (Stocks, futures, options, swap, and term)
Public Bonds (E)	Negative (–) for the public bonds segment (only this subsection)
Private Securities (E)	Negative (–) for the private securities segment (private securities, committed operation, and SPE)
Funds Segment—Fixed Income (E)	Negative (–) for the fixed income funds segment (fund shares, deposit, credit rights, and loan)

Source: Elaborated by the authors.

considering all the generated panels (simple linear regression, robust RE, and GMM) of the population; the GMM for the DB, DC, and VC plans; and the classification by size, small, medium, and large plans. There is statistical significance for the positive sign in almost all the segments of the Stock Segment (variable income); therefore, we inferred those allocations to assets in this higher-risk segment generate higher risk.

However, in the generated panels (simple linear regression, robust RE, and GMM) of the Public Bonds, Private Securities, and Funds Segment—Fixed Income Segments, those that have statistical significance are only concerning the population, DB plans, and medium-sized plans. Therefore, we inferred those allocations in lower-risk assets generate less risk, exclusively, in those cuts.

Analogous to Hypothesis 1, this study also verified the validity of Hypothesis 2: Allocations of higher/lower risk assets are generating higher/lower return, when the results of all the panels generated for the dependent variable Sharpe are analyzed (which considers portfolio return, risk-free assets, and standard deviation), in addition to simple linear regression; robust RE for classification by the type of plan, namely, Plans 1, 2, and 3 (DB, DC, and VC plans), and the classification by Size 2 (medium size plans) of the Stock Segment, from which we inferred that these allocations in higher-risk assets generate higher returns.

In analyzing the Sharpe variable in the other allocation segments, it can be seen 1) a linear regression panel of the Public Securities and RF Funds Segments, a robust RE panel of the Public Bonds and Private Securities Segments, the GMM of the RF Fund Segment of the population; 2) a robust RE panel of the Public Bonds Segment, of the DB plans; 3) a robust RE panel of the Public Bonds and Private Securities Segment, of medium-sized plans; and 4) a robust RE panel of the Public Securities Segment, of large-sized plans. Thus, we inferred that these allocations in assets with lower named risks generate lower returns.

Notably, however, the panels generated for the dependent variable Sharpe provide a simple linear regression, with robust RE for the classification by type of plan, namely, Plans 1, 2, and 3 (DB, DC, and VC plans); the classification by size, namely, Sizes 1, 2, and 3 (small, medium, and large plans); and the population's GMM (Arellano-Bond) method, referring to the Public Bonds, Private Securities, and RF Funds Segments, which had coherence in the positive and negative signs, and none in the statistical significance at 1%, 5%, and 10% between them.

The results of the dependent variable Risk are summarized in **Table 1**. The first explanatory variable L1 is derived from the GMM panels, meaning how much of the one found in the variable previous Risk justifies the finding in the variable upper Risk. This GMM method was applied to the population (from 2010 to 2017—set of allocations) for the classification by type of plan, namely, Plans 1, 2, and 3 (closed DB pension plans, DC, and VC), and classification by Sizes 1, 2, and 3 (small, medium, and large plans). Except for GMM (Arellano-Bond) by Size 1, in the other applications of panels using this method, the previous risk does not explain the higher risk, with a statistical significance of 1%.

Table 1. Panel data, the relationship between the dependent variable risk and the explanatory and control variables.

		Linear Regression	Robust RE Random Panel	GMM Arellano-Bond	GMM Arellano-Bond	GMM Arellano-Bond	GMM Arellano-Bond	GMM Arellano-Bond	GMM Arellano-Bond	GMM Arellano-Bond
Risk-Dependent variable	Literature	Population	Population	Population	Classification 1	Classification 2	Classification 3	Size 1	Size 2	Size 3
Explanatory Variable										
L1	_____	_____	_____	−0.1743*** (0.0062)	−0.1827*** (0.0119)	−0.1635*** (0.0097)	−0.1775*** (0.0107)	−0.0048 (0.0596)	−0.1823*** (0.0068)	−0.1792*** (0.0147)
Stock	+	0.0012*** (0.0000)	0.0012*** (0.0000)	0.0014*** (0.0001)	0.0011*** (0.0002)	0.0022*** (0.0006)	0.0016*** (0.0002)	0.0013*** (0.0004)	0.0015*** (0.0002)	0.0016*** (0.0003)
Public Bonds	−	−0.0001*** (0.0000)	−0.0001*** (0.0000)	−0.0005*** (0.0001)	−0.0009*** (0.0002)	0.0003 (0.0006)	−0.0003 (0.0002)	omitted	−0.0004** (0.0002)	−0.0004 (0.0002)
Private Securities	−	−0.0001*** (0.0000)	−0.0001*** (0.0000)	−0.0005*** (0.0001)	−0.0008*** (0.0002)	0.0003 (0.0006)	−0.0003 (0.0002)	0.0000 (0.0002)	−0.0004** (0.0002)	−0.0003 (0.0002)
RF Funds	−	−0.0002*** (0.0000)	−0.0002*** (0.0000)	−0.0005*** (0.0001)	−0.0009*** (0.0002)	0.0003 (0.0006)	−0.0003 (0.0002)	−0.0002 (0.0002)	−0.0004*** (0.0002)	−0.0002 (0.0003)
Control Variables										
Accumulated Savings	_____	0.0060*** (0.0008)	0.0060*** (0.0004)	0.0089*** (0.0009)	0.0092*** (0.0018)	0.0086*** (0.0013)	0.0091*** (0.0014)	0.0121 (0.0093)	0.0086*** (0.0009)	0.0089*** (0.0021)
Accumulated GDP	_____	−0.0024*** (0.0001)	−0.0024*** (0.0001)	−0.0025*** (0.0001)	−0.0022*** (0.0002)	−0.0023*** (0.0001)	−0.0027*** (0.0001)	−0.0033*** (0.0009)	−0.0025*** (0.0001)	−0.0021*** (0.0002)
Accumulated SELIC	_____	−0.0115*** (0.0003)	−0.0115*** (0.0003)	−0.0096*** (0.0003)	−0.0082*** (0.0007)	−0.0102*** (0.0005)	−0.0100*** (0.0006)	−0.0194*** (0.0038)	−0.0096*** (0.0004)	−0.0084*** (0.0008)
Accumulated IPCA	_____	−0.0011*** (0.0002)	−0.0011*** (0.0001)	−0.0008*** (0.0002)	−0.0007** (0.0003)	−0.0006** (0.0002)	−0.0011*** (0.0003)	0.0003 (0.0017)	−0.0009*** (0.0002)	−0.0004 (0.0004)
Final Size	_____	0.0000 (0.0000)	0.0000 (0.0000)	_____	_____	_____	_____	_____	_____	_____
Constant	_____	0.0003 (0.0000)	0.0003 (0.0000)	0.0005 (0.0001)	0.0009 (0.0002)	−0.0001 (0.0006)	0.0003 (0.0002)	0.0004 (0.0002)	0.0004 (0.0002)	0.0003 (0.0002)
Observation	_____	29.829	29.829	26.768	7.036	10.761	8.971	290	21.798	4.680
R2 of the Model	_____	0.48	0.89	_____	_____	_____	_____	_____	_____	_____
Panel	_____	RE	RE	_____	_____	_____	_____	_____	_____	_____
Year Dummy	_____	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Elaborated by the authors (the level of significance is *** 1%, ** 5%, and * 10% with the standard deviation of the coefficient in parentheses).

Notably, we had to apply GMM to the dependent variable Risk because the data demonstrated serial autocorrelation. This finding is important and indicates the consistency of the population data from the pension funds Investment Statements—Assets (IS) because the risk measured in a given period does not have to explain the risk determined in the next period.

Considering the relationship between the dependent variable Risk and the Stock Investment Segment (Stocks, Future, Options, Swap, and Term), it is posi-

tive (as expected in the literature) and has a statistical significance of 1% in all the round panel modalities, that is, in simple linear regression, robust RE, and the GMM (Arellano-Bond) referring to population/industry, as well as in the other GMM (Arellano-Bond) methods for classification by plan Types 1, 2, and 3 (DB, DC, and VC plans), in addition to the classification by Sizes 1, 2, and 3 (small, medium, and large plans). The coherence of the positive signs of the Stock Segment in all panels, with statistical significance at 1% and, in values higher than the other Segments (fixed income), show the consistency of the method and the data analyzed.

Regarding the relationship between the dependent variable Risk and the Public Bonds Segment (only this subsection), what the finance literature expected was a negative sign, that is, fixed income transactions have less risk than those of variable income. Of the panels analyzed, the simple linear regression and the robust RE of the population, in addition to the GMM (Arellano-Bond) classification by type of Plan 1 (DB plans) and the population, are negative and have a statistical significance of 1%. There was statistical significance in the GMM (Arellano-Bond) panel for Size 2 (medium) plans, and that was at 5%. In the other panels of the GMM method (Arellano-Bond), for the classification by type of Plans 2 and 3 (DC and VC plans), except for the classification by Size 3 (large plans), there was no statistical significance. The result of the panel with the GMM (Arellano-Bond) method of classification by Size 1 was omitted by Stata® because of the multicollinearity of the variables.

When observing the relationship between the dependent variable Risk and the Private Securities Segment (Private Securities, Committed Operation, and SPE), what the finance literature expected, as in the case of the Public Bonds Segment, was a negative sign, that is, fixed income operations have a lower risk than variable income, in theory. Of the panels analyzed, the simple linear regression and the robust RE of the population, in addition to the GMM (Arellano-Bond) classification by type of Plan 1 (DB plans) and the population, are negative and have a statistical significance of 1%. Analogous to what occurred with Public Bonds, there was a statistical significance of 5% in the GMM (Arellano-Bond) panel for Size 2 (medium) plans. In the other panels of the GMM method (Arellano-Bond) for the classification by type of plan, namely, 2 and 3 (DC and VC plans), except for the classification by Sizes 1 and 3 (small and large plans), there was no statistical significance.

Next, we analyzed the relationship between the dependent variable Risk and the Fund Segment—Fixed Income (Fund Shares, Deposit, Credit Rights, and Loan). What the finance literature expected, as in the case of the Public Bonds and Private Securities Segments, was a negative sign, that is, fixed income transactions have less risk than variable income transactions. Of the panels analyzed, the simple linear regression and the robust RE of the population, in addition to the GMM (Arellano-Bond) classification by type of Plan 1 (DB plans) of the population and by Size 2 (medium), are negative and have statistical significance

at 1%. In the other panels of the GMM method (Arellano-Bond) for the classification by type of plan, namely, 2 and 3 (DC and VC plans), except for the classification by Sizes 1 and 3 (small and large plans), there was no statistical significance.

Notably, the results of all the generated panels of the simple linear regression, with robust RE and in the population's GMM (Arellano-Bond), as well as in the other panels of the GMM (Arellano-Bond) methods for the classification by type of plan, namely, 1, 2, and 3 (DB, DC, and VC plans), in addition to classification by Sizes 1, 2, and 3 (the small, medium, and large plans, regarding), in the Public Bonds, Private Securities, and Funds Segments—Fixed Income, there was a coherence of negative signs, of statistical significance at 1% and 10%, and in panels where there was no statistical significance, corroborating the fact recorded in the Stock Segment, that is, there is consistency in the method and the analyzed data.

After presenting the data results in the panels of the dependent variable Risk, are demonstrated the results of the data in the panels of the dependent variable Sharpe, summarized in **Table 2**. This result is analogous to what occurred with Risk. The first explanatory variable L1 is derived from the panel of GMM, and the means of variation in the previous Sharpe explain the variation of the upper Sharpe. This GMM method was applied only to the population (from 2010 to 2017—set of allocations from closed Pension Fund plans), and we found that the previous Sharpe explains the upper Sharpe, with a statistical significance of 1%.

In contrast to what occurred with the dependent variable Risk, where we had to execute the GMM method, because the data presented serial autocorrelation, the application of the GMM for the dependent variable Sharpe was only in a complementary character, intending to harmonize the methods used for the two dependent variables.

Next, the relationship between the dependent variable Sharpe and the Stock Investment Segment (Stocks, Future, Options, Swap, and Term) was observed, with a positive relationship (analogous to what appears in the literature) and with statistical significance at 1%, in the modalities of the simple linear regression panel, in the robust RE, and in the GMM (Arellano-Bond) of the population, in addition to those of robust RE for the classification by type of plan, namely, 1, 2, and 3 (DB, DC plans, and VC), in addition to the classification by Size 2 (medium-sized plans). As for the robust random effect panels for the classification by Sizes 1 and 3 (small and large plans), there was no statistical significance.

When considering the relationship between the dependent variable Sharpe and the Public Bonds Segment (only this subsection), the finance literature predicted a negative sign, and such fixed income transactions would tend to yield a less than variable income, leading to taking into account what occurs in the most developed markets. The results found in the panels analyzed indicate that the simple linear regression and the robust RE of the population, in addition to those of robust RE of the classification by type of Plan 1 (DB plans) and the classification by Size 2 (medium plans), are negative and have statistical significance

Table 2. Panel data, the relationship between the dependent variable Sharpe and the explanatory and control variables.

		Linear Regression	Robust RE Random Panel	GMM Arellano-Bond	Robust RE Random Panel	Robust RE Random Panel	Robust RE Random Panel	Robust RE Random Panel	Robust RE Random Panel	Robust RE Random Panel
Sharpe-Dependent Variable	Literature	Population	Population	Population	Classification 1	Classification 2	Classification 3	Size 1	Size 2	Size 3
					Explanatory Variable					
L1	_____	_____	_____	0.03*** (0.01)	_____	_____	_____	_____	_____	_____
Stock	+	88841.17*** (4663.24)	78742.24*** (7744.69)	163764.40*** (35242.48)	50049.33*** (11333.07)	116850.90*** (21942.59)	74961.35*** (12499.88)	−12500000.00 (16700000.00)	89427.10*** (7860.93)	8556.52 (31605.79)
Public Bonds	−	−11317.75*** (3943.45)	−28015.47*** (6370.12)	30391.56 (33897.15)	−40894.69*** (8452.37)	−8375.56 (19916.05)	−17224.99 (12008.27)	−12700000.00 (16800000.00)	−28389.59*** (6487.23)	−48681.02* (27854.54)
Private Securities	−	20.40 (3961.39)	−11824.43* (6246.72)	53514.74 (33900.29)	−10332.33 (7977.34)	1486.24 (20100.40)	−9008.60 (11592.52)	−12700000.00 (16800000.00)	−10743.96* (6329.34)	−33168.91 (28964.05)
RF Funds	−	17477.53*** (4216.07)	1604.49 (6299.97)	62840.69* (34117.05)	1339.37 (8471.21)	21201.23 (19700.43)	1525.66 (12216.00)	−12600000.00 (16800000.00)	4712.12 (6333.87)	−41617.08 (30138.80)
					Control Variables					
Accumulated Savings	_____	633581.80*** (175036.30)	685033.90*** (149309.60)	1279347.00*** (189480.70)	122734.10 (308491.70)	1550367.00*** (248343.00)	135485.60 (216714.00)	2036240.00 (1303908.00)	891067.10*** (167774.10)	−386751.00 (302678.00)
Accumulated GDP	_____	40927.20* (21533.18)	39208.67** (19286.87)	17694.36 (17841.97)	−42835.35 (45962.23)	94547.42*** (28426.99)	28822.36 (29567.24)	−193107.30 (198113.80)	49961.33** (21832.78)	14954.28 (44651.78)
Accumulated SELIC	_____	−106209.40 (64510.96)	−136119.70*** (51993.76)	373311.00*** (70882.27)	−234305.20* (121891.30)	−217749.20** (84361.07)	4375.19 (72697.73)	−854666.60 (530275.90)	−136662.00** (58137.85)	−65361.89 (112796.10)
Accumulated IPCA	_____	74234.11** (36849.98)	73705.91** (29427.98)	221795.70*** (34036.81)	126118.70* (71021.12)	107653.90** (45808.58)	6007.31 (42958.03)	215320.80 (286041.70)	92140.77*** (32416.41)	−48742.30 (64772.33)
Final Size	_____	3033.18 (428.26)	2661.66 (1045.19)	1743.68 (3122.18)	5858.67 (1854.32)	2469.41 (1649.99)	1750.82 (1404.12)	_____	_____	_____
Constant	_____	−24885.27 (5241.22)	−10346.00 (7091.65)	−90450.40 (34208.80)	4553.82 (10148.91)	−43654.20 (20000.72)	−6408.91 (12744.19)	12600000.00 (16800000.00)	−10259.43 (6581.55)	42298.76 (28327.90)
Observation	_____	29.829	29.829	26.768	7.910	12.045	9.874	361	24.459	5.009
R2 of the Model	_____	0.09	0.28	_____	0.28	0.30	0.25	0.21	0.30	0.21
Panel	_____	RE	RE	_____	RE	RE	RE	RE	RE	RE
Year Dummy	_____	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: Elaborated by the authors (level of significance is *** 1%, ** 5%, and * 10%, with the standard deviation of the coefficient in parentheses).

at 1%. There is also statistical significance, however, at 10%, in the robust RE panel of the classification by Size 3 (large plans). In the other panels of the GMM method (Arellano-Bond) for the population, with robust RE for the classification by types of plan, namely, 2 and 3 (DC and VC plans), in addition to the classification by Size 1 (small plans); there was no statistical significance.

In the relationship between the dependent variable Sharpe and the Private Securities Segment (Private Securities, Committed Operation, and SPE), when in the financial literature a negative sign is predicted, analogous to the Public Bonds Segment, denoting the possibility of having lower profitability of fixed income operations when compared to variable income operations. In the analysis of the

panels, there is evidence of 10% statistical significance, in those with robust RE of the population and the robust RE of the classification by Size 2 (medium-sized plans). In the other panels of the variable Sharpe, that is, the simple linear regression and the GMM method (Arellano-Bond) of the population, in addition to those with robust RE classification by type of plan, namely, 1, 2, and 3 (DB, DC plans, and VC), and those for classification by Sizes 1 and 3 (small and large plans); there was no statistical significance.

Finishing the analysis of the relationship between the dependent variable Sharpe, now with the Fund Segment—Fixed Income (Fund Shares, Deposit, Credit Rights, and Loan), in the financial literature a negative sign is expected, along the same lines as the Segments of Public Bonds and Private Securities, considering that fixed income operations have lower profitability than variable income. In this relation, the only panel that has statistical significance at 1% is the simple linear regression of the population. Another statistical significance was found, however, at the level of 10%, in the panel of the population's GMM method (Arellano-Bond). In the other panels generated, the robust RE of the population, the robust RE of the classification by type of plan, namely, 1, 2, and 3 (DB, DC, and VC plans), and those of the classification by Sizes 1, 2, and 3 (small, medium, and large plans), no statistical significance was found.

In contrast to the results of all panels generated for the dependent variable Risk, the panels generated for the dependent variable Sharpe provide a simple linear regression, with robust RE for the classification by type of plan, namely, 1, 2, and 3 (DB plans, DC, and VC); the classification by Sizes 1, 2, and 3 (small, medium, and large plans); and the population's GMM (Arellano-Bond) method, referring to the Public Bonds Segments, Private Securities, and RF Funds, were not coherent in the positive and negative signs and the statistical significance at 1% and 10% between them.

The main conclusions of the research are presented in the next section and are based on the researched literature and the objectives outlined.

5. Conclusion

This article aimed to deepen the knowledge in the social security systems segment, mainly the Closed Complementary Pension Entities (EFPC, which is also known in Brazil as pension funds) by way of national and international literature review, but they had their power maximized by making the Investment Statements—Assets (IS) database available to all closed entities (from 2010 to 2017), through the Regulatory Agency, given the few studies worldwide that have or had access to the universe of primary information from a research field with great social and economic value such as social security; this point is another innovative aspect of this article.

A non-predictive econometric model with panel data was tested to verify the relationship between explanatory variables (Risk and Sharpe) and control variables (Savings, GDP, SELIC, and IPCA, accumulated quarterly). Simple linear

regressions, robust Random Effect (RE) regressions, and GMM (Arellano Bond) were generated, in addition to considering, the classification of the plans DB, DC, and VC, in addition to the classification of plans by size, namely, small, medium, and large, representing the analysis of the population of investment assets. The results suggest, when considering the closed pension funds segment as a whole, an indicator of industry efficiency throughout the historical series (from 2010 to 2017).

Care and responsibility should be exercised to address the results of academic studies involving the efficiency or inefficiency of closed pension funds, this segment is extremely complex and does not have the flexibility to promote reallocations of securities (fixed income) to stocks (variable income) and, vice-versa. Pension funds trade large volumes of financial resources and there may be restrictions from capital market regulators (i.e. trading large volumes may affect operations, influence prices, or promote asymmetries).

Further research can expand the spectrum shown in this study, with analyses of quarterly periods to attest to the efficiency of closed pension funds, measurement of the individual profitability of each closed pension plan, checking the composition of portfolios, the flow of contributions (i.e. if you have participants or sponsors contributing to the fund), the cash flows from financial investments (e.g. interest, coupons, dividends, interest on own capital, and distribution of stocks), and the amounts disbursed because all these factors influence profitability; and study the solvency of closed pension benefit plans.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Aglietta, M. et al. (2012). Rehabilitating the Role of Active Management for Pension Funds. *Journal of Banking & Finance, 36,* 2565-2574. https://doi.org/10.1016/j.jbankfin.2012.05.017

Amaral, H. F. et al. (2004). Pension Funds as Sources of Domestic Savings: An Alternative for Financing Economic Activity. *Journal of Contemporary Management (RAC), 8,* 137-158.

[1]PREVIC, National Supplementary Pension Superintendence; Ministry of Finance; Brazilian Complementary Pension Regulatory Agency, Brasília; Database of Investment Statements of Closed-End Pension Funds (2010 at 2017). Through the Electronic Information System (SEI). https://sei.previc.gov.br/sip/login.php?sigla_orgao_sistema=PREVIC&sigla_sistema=SEI&infra.

Assaf Neto, A. (2014). *Corporate Finance & Value* (7th ed.). Atlas.

BACEN (Brazilian Central Bank) (2020). *SELIC Daily Data*. https://www.bcb.gov.br/estabilidadefinanceira/selicdadosdiarios

Baima, F. R., & da Costa Jr., N. C. A. (2010). Benchmark Portfolio for Evaluating the Performance of Pension Funds. *Journal of Economics and Administration, 9,* 102-121.

Bicalho, F. C. (2018). *Evaluation of Investments by Supplementary Pension Funds in Brazil*. Master's Dissertation, Catholic University. https://bdtd.ucb.br:8443/jspui/handle/tede/2410

Boulier, J. F., Trussant, E., & Florens, D. (1995). A Dynamic Model for Pension Funds Management. *Proceedings of the 5th AFIR International Colloquium* (pp. 361-384). http://www.actuaires.org/AFIR/colloquia/Brussels/Boulier_Florens_Trussant.pdf

Broeders, D. W. G. A., Van Oord, A., & Rijsbergen, D. R. (2019). Does It Pay to Pay Performance Fees? Empirical Evidence from Dutch Pension Funds. *Journal of International Money and Finance, 93,* 299-312. https://doi.org/10.1016/j.jimonfin.2019.02.010

Cairns, A. J. G., & Parker, G. (1997). Stochastic Pension Fund Modelling. *Insurance: Mathematics and Economics, 21,* 43-79. https://doi.org/10.1016/S0167-6687(97)00018-8

Cunha Júnior, J. E. (2013). *Accounting Aspects of Pension Funds (2014)*. In *Event at Regius Civil Society for Private Pension*. https://docplayer.com.br/136922683-Aspectos-administrativos-e-contabeis-dos-fundos-de-pensao-brasilia-29-de-novembro-2013.html

Fávero, L. P. L. (2013). Panel Data in Accounting and Finance: Theory and Application. *Brazilian Business Review, 10,* 131-156. https://doi.org/10.15728/bbr.2013.10.1.6

Foo, J., & Witkowska, D. (2016). Investment Performance of US and European Pension Funds. A Comparative Analysis. *Aestimatio: The IEB International Journal of Finance, 13,* 90-109. https://dialnet.unirioja.es/servlet/articulo?codigo=5904080

Gollier, C. (2008). Intergenerational Risk-Sharing and Risk-Taking of a Pension Fund. *Journal of Public Economics, 92,* 1463-1485. https://doi.org/10.1016/j.jpubeco.2007.07.008

Gray, A. (1929). Pension and Superannuation Funds. *The Economic Journal, 39,* 280-281. https://doi.org/10.2307/2224564

Hoevenaars, R. P. M. M. et al. (2008). Strategic Asset Allocation with Liabilities: Beyond Stocks and Bonds. *Journal of Economic Dynamics and Control, 32,* 2939-2970. https://doi.org/10.1016/j.jedc.2007.11.003

IBGE—Brazilian Institute of Geography and Statistics (2020). *Historical Series of the Extended National Consumer Price Index—IPCA*. https://www.ibge.gov.br/estatisticas/economicas/precos-e-custos/9256

IPEA Data (2020). *Historical Series of Savings Income*. http://www.ipeadata.gov.br/ExibeSerie.aspx?serid=31878&Module=M

Marples, W. F. (1947). An Analysis of a Pension Fund. *Journal of the Institute of Actuaries, 73,* 66-98. https://doi.org/10.1017/S0020268100012026

Marques, L. D. (2000). *Dynamic Models with Panel Data: Literature Review* (pp. 1-84). Center for Macroeconomic Studies and Forecasting, Faculty of Economics of Porto. http://wps.fep.up.pt/wps/wp100.pdf

Nese, A. de A. S., & Giambiagi, F. (2020). *Fundamentals of Supplementary Pension: From Administration to Investment Management*.

Petraki, A., & Zalewska, A. (2017). Jumping over a Low Hurdle: Personal Pension Fund Performance. *Review of Quantitative Finance and Accounting, 48,* 153-190.

https://doi.org/10.1007/s11156-015-0546-9

Pinheiro, R. P. et al. (2005). Regulation of Investments in Pension Funds: Historical Evolution, Recent Trends and Regulatory Challenges. *UERJ Social Security Journal, 3,* 35-53.

Rabelo, F. M. (1998). Pension Funds, Capital Markets and Corporate Governance: Lessons for Emerging Markets. *Journal of Business Administration Magazine (RAE), 38,* 27-37.

Rieche, F. C. (2005). Risk Management in Pension Funds in Brazil: Current Status of Legislation and Perspectives. *Journal of the National Bank for Economic and Social Development (BNDES), 12,* 219-242. http://web.bndes.gov.br/bib/jspui/handle/1408/8194

Sharpe, W. F. (1976). Corporate Pension Funding Policy. *Journal of Financial Economics, 3,* 183-193. https://doi.org/10.1016/0304-405X(76)90002-7

Trowbridge, C. L. (1952). Fundamentals of Pension Funding. *Transactions of the Society of Actuaries, 4,* 101-132. https://www.soa.org/globalassets/assets/files/resources/essays-monographs/50th-anniversary/m-av99-1-02.pdf

Zhang, C. B. (2014). Mean-Variance Portfolio Selection for Defined-Contribution Pension Funds with Stochastic Salary. *The Scientific World Journal, 2014,* Article ID: 826125. https://doi.org/10.1155/2014/826125