



# A performance-based assessment of Turkish private pension funds: efficiency, scale economies, and competitiveness

Can Verberi<sup>1</sup> · Muhittin Kaplan<sup>2</sup> · Mehmet Kutluğhan Savaş Ökte<sup>3</sup>

Received: 23 June 2025 / Accepted: 18 December 2025  
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## Abstract

This study evaluates the performance of private pension providers via three dimensions—efficiency, economies of scale, and competitive structure—of the private pension sector in Türkiye using a multi-method approach. The study employs a three-stage approach: data envelopment analysis to measure technical efficiency, Tobit regression to identify determinants, and the Panzar–Rosse model and Herfindahl–Hirschman Index to assess market structure. The analysis utilises firm-level panel data from 21 pension companies over 2013–2022. The empirical findings reveal that larger firm size is associated with improved efficiency, although diminishing returns emerge at higher asset scales. Financial profitability enhances technical efficiency, whereas a higher equity ratio and investment in both interest-bearing and interest-free financial instruments reduce it. The results indicate limited competition in a monopolistic or collusive market structure, which, paradoxically, is linked to improved technical efficiency by allowing managers to better exploit strategic advantages.

**Keywords** Private pension system · Market structure · Panzar–Rosse model · Efficiency · Competition

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This article is based on the PhD thesis prepared at Istanbul University by Can Verberi.

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✉ Can Verberi  
canverberi@sirnak.edu.tr

Muhittin Kaplan  
muhittin.kaplan@ihu.edu.tr

Mehmet Kutluğhan Savaş Ökte  
mokte@istanbul.edu.tr

<sup>1</sup> Department of Economics, Sirnak University, 73100 Sirnak, Türkiye

<sup>2</sup> Department of Economics, Ibn Haldun Universtiy, 34480 Istanbul, Türkiye

<sup>3</sup> Department of Economics, Istanbul University, 34452 Istanbul, Türkiye



## Introduction

Successful private pension systems provide many economic benefits, including enhancing retirement income security, increasing long-term savings, and deepening of capital markets. Beyond these macroeconomic advantages, the main aim of private pension systems is to enhance the income and living standards of the elderly population. While individual contributions are essential for the success of private pension systems, the efficiency of pension providers and the competitiveness of the market in which they operate are even more critical for ensuring sustainable performance and adequate retirement income (Barr and Diamond 2006; Davis 2005). Firm performance can be assessed through measuring firm efficiency, while market-level dynamics can be evaluated by examining the structure and competitiveness of the pension system. In other words, the efficiency and competitiveness of private pension providers can be considered central in evaluating the overall effectiveness of the system, as efficient fund management and competitive market structures are essential for maximising returns, minimising costs, and ultimately enhancing the income and living standards of the elderly (Barr and Diamond 2006; Davis 2005). This study aims to analyse the structural competitiveness of the private pension market in Türkiye, measure the efficiency of pension companies, and identify the determinants of efficiency for policy guidance. An assessment of the overall level of competitiveness in the market provides insights into the dynamics that influence the performance of private pension providers in Türkiye.

A brief review of the empirical literature on the performance of private pension firms reveals that prior studies have largely been conducted along three main dimensions: pension fund efficiency, market structure, and economies of scale in the private pension industry (Jiao and Ye 2013; Antolin 2008a, b; Sepúlveda 2012; Bikker and de Dreu 2009). The operational performance of private pension funds is closely linked to their investment strategies, efficient use of resources, and prevailing macroeconomic conditions. Ultimately, their primary goal is to ensure sustainable value creation for contributors by efficiently managing portfolios and costs, with performance measured through technical and cost efficiency, and fund returns (Li et al. 2020; Anuno et al. 2024; Alda and Ferruz 2012; Barros and Garcia 2006). In this context, macroeconomic variables such as interest rates and inflation, alongside firm-level liquidity management strategies, can influence the ability of funds to maintain performance stability. Efficient liquidity use in particular enhances firms' capacity to balance short-term obligations and long-term investments (Li et al. 2020). Furthermore, the composition of financial assets—especially the proportion of interest-bearing versus interest-free instruments—significantly affects the risk-return profile, with interest-free instruments typically associated with higher volatility (Anuno et al. 2024).

Economies of scale is another determinant of fund performance. Economies of scale allow larger pension funds to reduce costs per client (Bikker et al. 2017). From a theoretical perspective, larger pension funds are often able to spread fixed administrative and investment costs over a broader asset base, thereby improving cost efficiency and net returns (Bikker and de Dreu 2009; Broeders et al. 2016). However, the relationship between scale and efficiency is not necessarily linear. Beyond a certain



threshold, increasing organisational complexity and managerial slack may erode the cost advantages of scale, leading to what Leibenstein (1966) defined as X-inefficiency—a form of internal inefficiency that arises when firms fail to fully utilise available resources due to weak motivation, information asymmetries, or ineffective monitoring. In large pension funds, these factors can reduce managerial effort and accountability, offsetting the initial efficiency gains from scale. Another important factor in the private pension fund market is the level of competition, which plays a critical role in shaping market performance and efficiency outcomes. Competition level and efficiency are closely linked, as variations in market structure can significantly influence how effectively firms operate (Bain 1951; Demsetz 1973). Competitiveness in the private pension fund market is shaped by provider numbers, market concentration, and regulation. While greater competition fosters innovation and cost efficiency, it may distort managerial incentives, leading to herding behaviour and reduced returns (Wang and Ye 2023). In contrast, less competitive markets can allow skilled managers to outperform consistently (Hoberg et al. 2018). Competition also drives investment differentiation strategies (Anthropelos et al. 2022), as increased competitive pressure encourages fund managers to adopt distinctive portfolio allocations and risk-sharing mechanisms to attract participants and signal superior performance. Thus, the optimal level of competition requires balancing efficiency gains with potential incentive misalignments.

In Türkiye, the private pension market constitutes the second-pillar private pension system, formally established under the Private Pension Savings and Investment System Law No. 4632. Pension assets are managed by private pension companies (pension fund management corporations) organised as joint-stock companies and supervised by the Insurance and Private Pension Regulation and Supervision Agency (SEDDK). Unlike trust-based pension schemes in many OECD countries, these companies operate as profit-oriented corporations that collect contributions and manage portfolios through distinct pension funds (Ertuğrul et al. 2018). Participants are free to switch providers, ensuring a competitive market environment.

Despite the breadth of international evidence on pension fund efficiency, these studies provide mixed results and differ significantly across countries and regions. Moreover, the literature on the factors influencing pension fund efficiency and the level of competition in the pension market in Türkiye is non-existent. It is also worth mentioning that no studies focusing on pension fund efficiency have examined the impacts of interest-bearing and interest-free financial asset classes<sup>1</sup> as well as technical profitability<sup>2</sup> and financial profitability<sup>3</sup> on the efficiency level of pension funds in Türkiye.

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<sup>1</sup> Interest-bearing assets include fixed-income instruments such as treasury bills and government bonds that generate predetermined interest payments. Interest-free assets include shares, other equity, and mutual fund participation certificates, which do not yield fixed interest but instead provide dividends or capital gains.

<sup>2</sup> Technical profitability is measured as the ratio of technical surplus (premium income minus benefit payments and administrative expenses) to total premiums or total assets, reflecting operational and administrative efficiency.

<sup>3</sup> Financial profitability is proxied by the ratio of investment income (including interest revenues, dividends, and capital gains) to total assets under management, representing investment performance.



Taken together, this study contributes to the existing literature in four ways. Firstly, it investigates the determinants of pension fund efficiency in Türkiye. Secondly, it explores the level of competition in the pension market and its effect on pension fund efficiency. Finally, it analyses the effect of interest-bearing and interest-free financial asset classes, technical profitability, and financial profitability on the pension fund efficiency level in Türkiye.

Based on the theoretical approaches and empirical literature, the following hypotheses are developed to guide the analysis:

**H1** Larger pension firms are expected to be more efficient due to economies of scale.

**H2** Older firms are expected to show higher efficiency owing to accumulated experience and learning effects.

**H3** Higher market concentration may improve efficiency through cost advantages, yet excessive concentration can reduce competitive pressure.

**H4** Foreign and public ownership are expected to enhance efficiency through better governance, expertise, and regulatory oversight.

**H5** Financially and technically more profitable firms are expected to be more efficient.

**H6** A higher share of interest-bearing assets increases efficiency, while more interest-free assets may lower it due to limited liquidity.

**H7** The private pension market is theoretically expected to operate under a monopolistic competition structure, where firms compete in a differentiated but not perfectly competitive environment.

The rest of the paper is structured as follows. In the next section, an overview of the existing literature is presented. The model, data, and methodology employed are outlined in the third section. The penultimate section presents the empirical findings, and the final section presents the conclusions and implications.

## Literature review

This section reviews the empirical literature on the efficiency of private pension firms, economies of scale, and the level of competition in private pension market (see Tables 8, 9 and 10 in the Appendix for a summary of the empirical literature).

### Measuring the level and determinants of efficiency for private pension providers

A brief review of the literature on the subject reveals that there are many studies on the determinants of pension fund performance, indicating that pension fund efficiency is influenced by various factors. Nevertheless, no study has analysed the deter-



minants of pension fund performance in Türkiye. Seran et al. (2023) use a two-stage additive network data envelopment analysis (DEA) to evaluate the efficiency of pension funds in Indonesia from 2011 to 2017. They found that the primary driver of pension fund efficiency is investment efficiency. In a similar vein, Tang and Mitchell (2008) investigate the efficiency of investment menus offered by defined contribution pension plans in the US during the period 1998–2002. Employing the Probit model, they propose that the types of funds offered are a crucial factor in determining pension plan efficiency. Alda and Ferruz (2012) employ the ordinary least squares (OLS) approach to assess the efficiency of private pension funds in Spain using data spanning 1999–2010. Their analysis reveals a negative association between higher fees and fund performance. Meanwhile, Yan and Foong (2021) examine the investment performance of private pension funds in five Asian countries, namely Hong Kong, Malaysia, Singapore, South Korea, and Thailand, utilising a six-year sample. They employ an OLS estimator and, similar to Alda and Ferruz (2012), discover that private pension funds in Asia generally underperform in the market. Furthermore, they observe a detrimental impact of management fees on fund performance. Shifting focus to Portugal, Barros and Garcia (2006) evaluate the performance of Portuguese private pension companies from 1994 to 2003 using DEA, incorporating both operational and financial variables. Their analysis unveils that scale, privatisation, and mergers and acquisitions significantly influence the efficiency of pension fund companies. In a subsequent study, Barros and Garcia (2007) employ the stochastic cost frontier model to gauge the cost efficiency of Portuguese pension funds using a dataset from 1994 to 2003. Their findings suggest that the price of labour, capital-management services, and capital-premises, profits, number of participants and closed funds, and the decision to manage open funds all play pivotal roles in determining the efficiency of such companies. Similarly, Mazreku et al. (2020) conduct a comparative analysis of the financial performance of pension funds in three Balkan countries using various methodologies, including regression, fixed effects models, random effects models, and Hausman Taylor regression. Their study demonstrates that GDP, return on investment, contributions, and net assets positively impact the performance of pension funds. Lastly, Guillen (2008) undertakes a comparison of the efficiency and rate of return of private pension funds in 10 Latin American countries, namely Argentina, Bolivia, Chile, Colombia, Costa Rica, El Salvador, Mexico, Peru, the Dominican Republic, and Uruguay. Utilising DEA and OLS methods, the author identifies a positive correlation between local economic benefit and the rate of return of pension funds. Furthermore, the study reveals variations in efficiency scores across countries and over time.

Interestingly, there are only a limited number of studies that analyse the relationship between ownership and pension fund performance, in both Türkiye and other countries. The results obtained from these studies show that pension companies with private and foreign ownership are more efficient than those with public, domestic, and bank-affiliated ownership. Using a sample of US firms from 1985 to 2005, Jiao and Ye (2013) examine the correlation between ownership of public pension funds and firm performance. Their findings reveal a pattern that follows an inverted-U shape, indicating that moderate ownership, which displays partial foreign shareholding below the controlling threshold (less than 50%), of public pension funds can



enhance shareholder value. However, prior research indicates that when public pension funds hold excessively large ownership stakes the likelihood of politically motivated investment decisions increases, which may ultimately undermine shareholder value (Andonov et al. 2018; Albuquerque et al. 2017). Mfoutou and Danquah (2022) utilise a DEA-adjusted estimator to evaluate the efficiency of defined-benefit private and public pension plans in the Republic of Congo. They apply a constant return to scale (CRS) adjusted estimator input and output orientation to a dataset spanning from 2011 to 2020. The study demonstrates that the private sector outperforms the public and industry sectors in terms of cost reduction and returns on investment. Kurtaran et al. (2013) conduct a study focusing on the development and efficiency of the private pension system in Türkiye. They employ DEA as a measurement tool to assess the relative efficiency of pension companies operating in Türkiye between 2004 and 2011. The results indicate that large-scale company groups exhibit lower efficiency compared to small-scale companies. Additionally, domestic companies demonstrate lower efficiency compared to foreign companies. Gökçen et al. (2020) investigate the influence of firm boundaries and incentives on the performance of pension funds in Türkiye. In Türkiye, private pension companies can either be affiliated with a bank or operate independently. The study utilises a dataset spanning from 2003 to 2014 and employs the pooled OLS method. The findings suggest that bank-affiliated pension funds underperform independent pension funds. In a more recent contribution, Lin and Lu (2024) apply a shared input dynamic network DEA model to evaluate the efficiency of Taiwan's Public Service Pension Fund over the 2008–2020 period. Their results show that ownership structure has a critical influence on dynamic efficiency, with private fund managers performing significantly better than state-owned ones. These findings further reinforce the view that institutional ownership characteristics play a decisive role in shaping pension fund performance across different national contexts.

A very limited number of studies have analysed the relationship between regulatory and legislative changes and pension fund performance, including in Türkiye and other countries. They have found that restrictions have a negative impact on pension fund performance, while regulatory changes improve market efficiency. Antolin (2008a, b) employs the Sharpe ratio approach to gauge the performance of pension funds in various OECD, Latin American, and Central and Eastern European (CEE) nations. The findings indicate that pension funds generally exhibit lower performance compared to market benchmarks, primarily due to investment restrictions. Mitkova and Mlynarovič (2020) undertake an examination of efficiency within the Slovak private pension funds markets, as well as the effects of legislative changes, utilising the effective frontier in Cvar-return space. The study utilises data spanning from 2005 to 2009 and reveals significant interactions between legislative changes and investment decisions. Erzurumlu and Ucardag (2021) employ fixed effect, random effect, and random effect within and between effect panel data analyses to assess the efficiency of private pension companies in Türkiye, utilising panel data encompassing all pension funds from 2011 to 2019. The study discovers a shift in investor sentiment from performance to cost subsequent to regulatory changes that enhanced market efficiency and compensated investors.



Studies focusing on pension fund efficiency in Türkiye usually concentrate on the efficiency ranking of private pension companies. In addition, they have found that the private pension company with the highest efficiency score changes from year to year. Demir et al. (2020) use grey relational analysis (GRA) to assess the performance of private pension companies in Türkiye, using data from 2017. Their findings reveal that Garanti, Anadolu, and Allianz Life and Insurance Company demonstrate the highest performance, whereas AXA, Aegon, and Fiba Pension and Life Company display the lowest performance among the 18 companies studied. Çamlıbel (2022) evaluates the performance of 10 life and pension companies in Türkiye by employing the stochastic data envelope analysis (SD) and multi-attribute ratio analysis (MARCOS) methods, covering the period 2015–2019. The results indicate that the SD method outperforms the MARCOS method in ranking the companies and identifying the best and worst performers. Furthermore, it is observed that Garanti Pension and Life and Ziraat Life and Pension companies exhibit the most favourable financial performance. Durgut (2022) employs the SWARA-SD-MAIRCA decision model to gauge the performance of 13 private pension companies in Türkiye, using data from 2015 to 2020. The findings reveal that Garanti Pension and Life stands out as the most successful company, while Aegon Pension and Life is deemed the least successful among the sample. Gurol and Imam (2018) pursue a distinct approach based on the TOPSIS multi-criteria decision-making method, which ranks alternatives in accordance with their relative proximity to an ideal solution, employing a dataset from 2006 to 2016. The application of this method to a sample of Turkish pension funds yields the highest performance in 2008, while the lowest performance is observed in 2006. Demirtaş and Keçeci (2020) implement the DEA model to evaluate the efficiency of private pension companies in Türkiye, using a panel of 16 firms spanning the period 2013–2016. Their findings indicate that the efficiency score can be enhanced by considering the effects of the inter-relations among consecutive periods.

### **Market competition**

Few studies examine the level of market competition in the pension fund market and the effects of the sales force, which denotes the network of agents and intermediaries that market and distribute pension fund products to potential participants, on competition. Furthermore, no studies have measured the level of competition in the pension fund market or the effects of competition on pension fund efficiency in Türkiye. Existing studies reveal that the pension fund market often exhibits a structure similar to a cartel or monopoly, and that the presence of a sales force reduces price sensitivity. In a study conducted by Hastings et al. (2017), the authors investigate the influence of the sales force on competition and equilibrium prices within the private pension market. To do so, they analyse comprehensive administrative data on the choices made by fund managers and the characteristics of workers from 1997 to 2007, with specific focus on the inception of Mexico's privatised social security system. They develop and estimate a model that incorporates the impact of the sales force on customer price sensitivity using logit and benchmark models. The results indicate that exposure to the sales force decreases price sensitivity, leading to less responsive demand



and higher fees in equilibrium. Additionally, they conduct simulations to evaluate the potential impacts of various policy solutions, such as prohibiting commissions, implementing price caps, or enhancing financial literacy. Sepúlveda (2012) applies this methodology to estimate the degree of competition among pension fund administrators in the Chilean private pension system from 1996 to 2008. The findings suggest that the industry can be characterised as a cartel or monopoly during this period, and there is a negative and statistically significant correlation between concentration and competition. Furthermore, he discusses the implications of these findings for proposed reforms aimed at increasing competition within the industry.

## Economies of scale

Several studies examine the existence of economies of scale. However, there is a lack of country-specific empirical evidence examining whether such scale effects exist in the Turkish private pension fund market. Previous studies usually verify the existence of economies of scale in pension funds. Mama et al. (2011) conduct a study of economies of scale and pension fund plans in South Africa, using OLS and SUR using data from 1996 to 2006. They find that South African pension funds exhibit significant economies of scale, but not economies of scope—that is, cost advantages arising from combining related activities such as insurance, asset management, or IT operations—and that the defined benefit plans are more efficient than defined contribution plans. This difference in efficiency can be explained by the structural characteristics of defined benefit plans, which can benefit from scale economies in investment management (Broeders and van Oord and Rijsbergen 2016) and from lower overall unit costs (Bikker and de Dreu 2009). However, this advantage is not universal. The efficiency of defined contribution plans depends on design features such as investment pooling, payout-phase regulation, and post-retirement asset management (Antolin 2008a, b). Differences in lifecycle asset allocation and plan design further explain variation in defined contribution retirement outcomes (Poterba et al. 2006). Broeders et al. (2016) provide a comprehensive analysis of the relation between investment costs and pension fund size, using a unique dataset of 225 Dutch occupational pension funds with a total of EUR 928 billion in assets under management in 2013. They decompose investment costs for six asset classes in management costs and performance fees, and find significant economies of scale in fixed income, equity, and commodity portfolios, but not in real estate investments, private equity, and hedge funds. Similarly, Bikker and de Dreu (2009) use a regression analysis to estimate the cost efficiency of pension funds in all Dutch pension funds using a dataset from 1992 to 2004. They find that scale has significant effects on the operating costs of pension funds. Agostini et al. (2012) use data from 1994 to 2012 and find that Chilean pension funds exhibit significant economies of scale and scope. Higgs and Worthington (2012) use regression analysis and a dataset from 2011 and find that Australian pension funds exhibit significant economies of scale. However, some studies find inconclusive results on the existence of economies of scale. Alserda et al. (2018) use a unique supervisory dataset from the Netherlands, which distinguishes between administrative and investment costs. They apply various approaches and models, such as stochastic cost frontier analysis and cost elasticity, to estimate the optimal scale and cost performance of



pension funds. The study covers the period from 1992 to 2013. The main findings are that there are large economies of scale for pension fund administrations, but modest diseconomies of scale for investment activities. Bikker and Meringa (2022) examine the scale effects on the cost margins of pension fund investment portfolios in the Netherlands using a panel data of 280 pension funds over the period 2012–2019. The findings are inconclusive. Bikker and Meringa (2024) further explore this issue by employing regression analysis on panel data from Dutch pension funds between 2007 and 2022. Their findings indicate that although large funds benefit from lower cost ratios and more diversified asset allocations, these advantages are offset by high performance fees and ineffective hedging strategies. As a result, the five largest funds do not outperform smaller ones in terms of net investment returns, suggesting that scale economies are not automatically realised and depend heavily on managerial execution quality.

Although several studies examine pension fund efficiency in relation to factors such as regulatory reforms, ownership structure, and fund size, they often overlook the combined effects of financial asset composition, technical profitability, and financial profitability on efficiency outcomes. Additionally, very limited studies investigate the level of competition in the pension fund market. In contrast, in Türkiye, no studies utilising various methodologies investigate the determinants of pension fund efficiency, the level of competition in the pension fund market, the effects of competition on pension fund efficiency, or the existence of economies of scale in private pension funds. In addition, the study on both Türkiye and other countries rarely considers the role of interest-bearing and interest-free financial assets, technical profitability, and financial profitability in shaping pension fund efficiency outcomes.

In this study, we aim to address the gaps in the existing literature highlighted in the introduction by examining the competition level of the private pension market, determinants of efficiency, the effects of competition on pension fund efficiency, and the existence of economies of scale in private pension companies in Türkiye. Additionally, we investigate the link between interest-bearing and interest-free financial asset classes, technical profitability, and financial profitability on pension fund efficiency level in Türkiye.

## **Dataset, methodology, and model**

This study assesses the competitiveness level of the private pension market and the determinants of efficiency in private pension companies. In this context, the sample covers 21 private pension companies operating in Türkiye during the 2013–2022 period; firm-year coverage varies across companies due to mergers, acquisitions, rebranding, and regulatory restructuring. Accordingly, the dataset represents an unbalanced panel that reflects genuine market dynamics rather than sample attrition (see Table 7 for detailed information and Tables 11 and 12 for summary statistics in the Appendix). Missing-year observations primarily stem from corporate transformations or incomplete filings rather than deliberate exclusion, ensuring proportional representation of all active providers. Before estimation, correlation coefficients were calculated to assess potential multicollinearity. Most variable pairs did not exceed



the conventional 0.70 threshold; however, the two market concentration indicators—HHITASSET (asset-based) and HHICONT (contribution-based)—displayed correlations above 0.7. Therefore, they were included in separate model specifications to prevent redundancy (see Tables 13 and 14 for the correlation matrices).

In this study, a multi-method approach is adopted to evaluate the performance dynamics of private pension companies. Initially, DEA is employed to measure the efficiency scores of pension providers. Following the estimation of efficiency, the Tobit regression model is applied to investigate the firm-specific and macroeconomic determinants of these efficiency scores, recognising that DEA outcomes are censored and bounded between 0 and 1. The relationship between efficiency and market structure is further examined through the Panzar–Rosse model. To complement this, the Herfindahl–Hirschman Index (HHI) is utilised as a structural measure of market concentration. The sequential use of these methods is designed to move from internal performance assessment (DEA) to the exploration of explanatory factors (Tobit), and finally to external market dynamics (Panzar–Rosse and HHI), thereby offering a comprehensive analysis of both efficiency and competitive conditions in the private pension sector.

To empirically investigate the determinants of efficiency and market structure in the private pension sector, a set of regression models comprising five models is implemented. The first four models (Models I–IV) estimate the drivers of firm-level efficiency using censored regression (Tobit) due to the bounded nature of the dependent variable, namely DEA-based efficiency scores ranging between 0 and 1. The fifth model (Model V) employs the Panzar–Rosse methodology to evaluate the competitive conduct of firms by analysing the responsiveness of revenues to input price changes. The empirical model specifications are presented as follows:

Model I:

$$\begin{aligned} \text{INEFFICIENCY}_{it} = & \beta_1 \text{TOTASSET}_{it} + \beta_2 \text{TOTASSET2}_{it} + \beta_3 \text{AGE}_{it} + \beta_4 \text{HHICONT}_{it} \\ & + \beta_5 \text{FINANCIAL}_{it} + \beta_6 \text{TECHNICAL}_{it} + \beta_7 \text{EQUITY}_{it} + \beta_8 \text{FOREIGN}_{it} \\ & + \beta_9 \text{PUBLIC}_{it} + \beta_{10} \text{EDUC}_{it} + \beta_{11} \text{BINT}_{it} + \beta_{12} \text{FINT}_{it} + \epsilon_{it} \end{aligned} \quad (1)$$

Model II:

$$\begin{aligned} \text{INEFFICIENCY}_{it} = & \theta_1 \text{TOTASSET}_{it} + \theta_2 \text{TOTASSET2}_{it} + \theta_3 \text{AGE}_{it} + \theta_4 \text{HHITASSET}_{it} \\ & + \theta_5 \text{FINANCIAL}_{it} + \theta_6 \text{TECHNICAL}_{it} + \theta_7 \text{EQUITY}_{it} + \theta_8 \text{FOREIGN}_{it} \\ & + \theta_9 \text{PUBLIC}_{it} + \theta_{10} \text{EDUC}_{it} + \theta_{11} \text{BINT}_{it} + \theta_{12} \text{FINT}_{it} + v_{it} \end{aligned} \quad (2)$$

Model III:

$$\begin{aligned} \text{INEFFICIENCY}_{it} = & \gamma_1 \text{AGE}_{it} + \gamma_2 \text{HHICONT}_{it} + \gamma_3 \text{FINANCIAL}_{it} + \gamma_4 \text{TECHNICAL}_{it} \\ & + \gamma_5 \text{EQUITY}_{it} + \gamma_6 \text{FOREIGN}_{it} + \gamma_7 \text{PUBLIC}_{it} \\ & + \gamma_8 \text{EDUC}_{it} + \gamma_9 \text{BINT}_{it} + \gamma_{10} \text{FINT}_{it} + t_{it} \end{aligned} \quad (3)$$

Model IV:

$$\begin{aligned} \text{INEFFICIENCY}_{it} = & \delta_1 \text{AGE}_{it} + \delta_2 \text{HHITASSET}_{it} + \delta_3 \text{FINANCIAL}_{it} + \delta_4 \text{TECHNICAL}_{it} \\ & + \delta_5 \text{EQUITY}_{it} + \delta_6 \text{FOREIGN}_{it} + \delta_7 \text{PUBLIC}_{it} \\ & + \delta_8 \text{EDUC}_{it} + \delta_9 \text{BINT}_{it} + \delta_{10} \text{FINT}_{it} + n_{it} \end{aligned} \quad (4)$$



Model V:

$$\text{LNTPROFIT}_{it} = \phi_1 \text{FIXED}_{it} + \phi_2 \text{PERSON}_{it} + \phi_3 \text{COM}_{it} + \phi_4 \text{EQUITY}_{it} + s_{it} \quad (5)$$

The dependent variable in Models I–IV is  $\text{INEFFICIENCY}_{it}$ , calculated as the inverse of DEA-based efficiency scores derived from firm-level input-output data.<sup>4</sup> Firm size is measured by total assets in logarithmic form ( $\text{TOTASSET}$ ), and its square ( $\text{TOTASSET}^2$ ) accounts for potential non-linear effects.  $\text{AGE}$  denotes the number of years since a firm’s establishment. Market concentration is proxied using Herfindahl–Hirschman Indices:  $\text{HHICONT}$ , based on contribution amounts, and  $\text{HHITASSET}$ , based on total assets. Capital structure and profitability dynamics are represented by  $\text{EQUITY}$ —the ratio of shareholders’ equity to total assets, capturing the financial stability and leverage position of private pension companies— $\text{FINANCIAL}$  (financial profit relative to assets), and  $\text{TECHNICAL}$  (technical profit relative to assets). Ownership structure is identified through dummy variables:  $\text{FOREIGN}$ , which equals 1 if foreign ownership exceeds 50%, and  $\text{PUBLIC}$ , which equals 1 if public ownership exceeds 50%, reflecting the influence of state ownership on governance and performance outcomes. Human capital is captured by  $\text{EDUC}$ , defined as the share of personnel holding a university, master’s, or doctoral degree. Governance and asset composition are proxied by two financial asset types:  $\text{BINT}$ , the ratio of interest-bearing financial assets to total assets, and  $\text{FINT}$ , the corresponding ratio for interest-free financial instruments. In the Panzar–Rosse framework (Model V), which is used to assess the degree of market competition, the dependent variable is  $\text{LNTPROFIT}$ , the natural logarithm of total revenue. The model includes cost-related input factors such as  $\text{FIXED}$  (total fixed costs as a share of assets),  $\text{PERSON}$  (personnel expenses relative to assets), and  $\text{COM}$  (commission expenses as a share of assets), in addition to  $\text{EQUITY}$  (total equity as a share of assets) (See Table 1 for details). Finally,  $\epsilon_{it}$ ,  $v_{it}$ ,  $t_{it}$ ,  $n_{it}$ , and  $s_{it}$  represent the error terms in Models I–V, respectively.

The use of multiple models allows for a robust analysis of various explanatory dimensions by incrementally incorporating key variables. Model I includes  $\text{HHICONT}$  (market concentration based on contributions) and  $\text{TOTASSET}^2$  to capture the non-linear effects of firm size and the impact of market structure. Model II substitutes  $\text{HHITASSET}$  (concentration based on total assets) for  $\text{HHICONT}$  while retaining  $\text{TOTASSET}^2$ , thus testing whether different concentration metrics yield consistent effects. Model III focuses solely on the impact of  $\text{HHICONT}$  to isolate

<sup>4</sup>In this study, technical efficiency scores were first obtained through an input-oriented DEA model under the assumption of variable returns to scale (VRS). The DEA estimates range between 0 and 1, where 1 indicates full efficiency and values below 1 indicate relative inefficiency compared to the best-practice frontier. To incorporate these scores into the Tobit regression, an inefficiency measure was constructed as the inverse of the DEA efficiency score minus 1, following the approach of Charnes et al. (1978) and Barros and Garcia (2006). Accordingly, inefficiency is defined as  $\left[ \text{INEFFICIENCY}_{it} = \frac{1}{\text{Efficiency score}_{it}} - 1 \right]$ ,

which allows for a continuous and positive measure of inefficiency, suitable for censored regression analysis.



**Table 1** Data sources and variable definitions

Variable	Definition	Source
INEFFICIENCY	Inefficiency score $([\text{INEFFICIENCY}_{it} = \frac{1}{\text{Efficiency}_{score_{it}}} - 1])$	Own calculation (derived from datasets of the Insurance and Private Pension Regulation and Supervision Authority and the Insurance Association of Türkiye)
LNTPROFIT	The natural logarithm of total revenue, TRY	
EQUITY	Total equity, TRY (% total asset)	
TOTASSET	Total asset (TRY billion)	
TOTASSET2	Square of total assets	
AGE	Firm age	
HHICONT	HHI calculated using the contribution amounts obtained by pension firms	
HHITASSET	HHI calculated using the total assets of pension firms	
FINANCIAL	Financial profit, TRY (% total assets)	
TECHNICAL	Technical profit, TRY (% total assets)	
FOREIGN	1 if foreign ownership percentage is more than 50%; otherwise, 0	
PUBLIC	1 if public ownership percentage is more than 50%; otherwise 0	Insurance and Private Pension Regulation and Supervision Authority and Insurance Association of Türkiye
EDUC	Ratio of personnel with university, master's, and doctoral degrees to total personnel	
BINT	Interest-bearing financial assets (treasury bills and government bonds), TRY (% total assets)	
FINT	Interest-free financial assets (shares, other equity, and mutual fund participation certificates), TRY (% total assets)	

its contribution without non-linear firm size controls, whereas Model IV includes only HHITASSET for a parallel assessment. These specifications allow the analysis to disentangle how alternative proxies for market concentration interact with other firm-specific variables. Finally, Model V employs the Panzar–Rosse methodology to assess the degree of competition in the private pension market by estimating the revenue elasticity with respect to input prices (Table 1).

Technical efficiency, which represents a firm's ability to maximise output given a set of inputs, is a fundamental performance metric in financial and pension fund studies because it reflects the firm's internal resource utilisation independent of price or market effects (Barros and Garcia 2006; Kurtaran et al. 2013; Guillen 2008). DEA is a non-parametric method in operations research and economics for the estimation of production frontiers. DEA is particularly suitable for this type of research (Charnes et al. 1978): (i) it does not require a specific functional form of the production function, (ii) it handles multiple inputs and outputs simultaneously, and (iii) it allows comparison among decision-making units with different scales of operation, which fits the heterogeneous structure of Turkish pension companies. It is used to empirically measure the productive efficiency of decision-making units, which can be calculated using the following linear programming problem (Charnes et al. 1978):

$$\text{Maximise } Z = \frac{\sum_{r=1}^s u_r \cdot y_{ro}}{\sum_{i=1}^m v_i \cdot x_{io}} \quad (6)$$



Subject to:

$$\frac{\sum_{r=1}^s u_r \cdot y_{rj}}{\sum_{i=1}^m v_i \cdot x_{ij}} \leq 1, \forall j \in \text{DMUs} \quad u_r, v_i \geq 0, \forall i, r$$

where  $Z$  is the efficiency score of the decision-making unit being evaluated;  $s$  represents the number of outputs;  $m$  refers to the number of inputs;  $y_{ro}$  presents the amount of output  $r$  produced by the decision-making unit being evaluated;  $x_{io}$  is defined as the amount of input  $i$  used by the decision-making unit being evaluated;  $y_{rj}$  and  $x_{ij}$  are the amounts of outputs and inputs for each decision-making unit ( $j$ ); and  $u_r$  and  $v_i$  are the weights to be determined for outputs and inputs, respectively. In this study, the DEA model employs the natural logarithm of total revenue (LNT-PROFIT) as the single output variable, representing the overall performance of pension companies. The input variables consist of LNFIXED, LNPERSON, LNCOM, and LNEQUITY. These inputs reflect, respectively, capital intensity, labour utilisation, operational expenses, and financial capacity of each firm. The inefficiency score (INEFFICIENCY) of the decision-making units being evaluated is calculated using the following formula:

$$\text{INEFFICIENCY} = (1/Z) - 1 \tag{7}$$

The Tobit model is a statistical regression model used to analyse censored or truncated data. It assumes that there is a latent variable that follows a linear relationship with the independent variables but is only observed when it lies within the censoring or truncation limits. The model can be specified as follows (Robin 2010):

$$y_i^* = x_i\beta + \epsilon_i \tag{8}$$

where  $y_i^*$  is the latent variable,  $x_i$  is a vector of independent variables,  $\beta$  is a vector of parameters, and  $\epsilon_i$  is an error term that follows a normal distribution with mean 0 and variance  $\sigma^2$ .

The Panzar–Rosse model is a non-structural method to assess the degree of competition in a market, based on the relationship between the revenues and input prices of firms. The main idea of the model is to estimate the elasticity of total revenue with respect to input prices, which is called the H-statistic. The value of the H-statistic can indicate the type of market structure, as follows (Panzar and Rosse 1987):

- If  $H \leq 0$ , the market is monopolistic or collusive.
- If  $H = 1$ , the market is perfectly competitive.
- If  $0 < H < 1$ , the market is monopolistically competitive.

The H-statistic can be estimated using a reduced-form revenue equation, which relates the total revenue of a firm to its input prices and other control variables, such as output, fixed costs, and market characteristics:

$$R_i = f(P_i, X_i, Z_i) + \epsilon_i \tag{9}$$



where  $R_i$  is the total revenue of firm  $i$ ,  $P_i$  is a vector of input prices,  $X_i$  is a vector of output or scale variables,  $Z_i$  is a vector of other control variables, and  $\epsilon_i$  is an error term. The H-statistic can be written as (Baarsma and Vooren 2018):

$$H = \sum_{j=1}^n \frac{\partial R_i}{\partial P_{ij}} \frac{P_{ij}}{R_i} \quad (10)$$

where  $n$  is the number of input prices, and  $P_{ij}$  is the  $j$ -th input price of firm  $i$ . The H-statistic can be estimated by using different functional forms for the revenue equation, such as linear, log-linear, or translog. The most common functional form used in the literature is the log-linear form, which can be written as:

$$\ln R_i = \alpha_0 + \sum_{j=1}^n \alpha_j \ln P_{ij} + \sum_{k=1}^m \beta_k \ln X_{ik} + \sum_{l=1}^p \gamma_l Z_{il} + \epsilon_i \quad (11)$$

where  $m$  is the number of output or scale variables, and  $p$  is the number of other control variables. The H-statistic is then equal to the sum of the coefficients of the input prices, that is:

$$H = \sum_{j=1}^n \alpha_j \quad (12)$$

HHI is a measure of market concentration and competition, based on the market share of the firms in a given industry. The formula for the HHI index is (Zeković and Perić 2023):

$$HHI = \sum_{i=1}^z s_i^2 \quad (13)$$

where  $z$  is the number of firms in the industry, and  $s_i$  is the market share of the  $i$ -th firm, expressed as a percentage. In this study, LNTPROFIT is used as the dependent variable in the DEA analysis and in the Panzar–Rosse model, while FIXED, PERSON, and COM as a proxy for the price of physical capital, an approximation of the wage rate, and a proxy for the price of intermediation in obtaining pension contributions are employed as input variables following Bikker et al. (2012), Sepúlveda (2012), and Çelik and Kaplan (2007). Additionally, the EQUITY variable is utilised as a control variable in the Panzar–Rosse model following Sepúlveda (2012). Finally, in the analysis of the determinants of efficiency for private pension firms, INEFFICIENCY is used as the dependent variable, while TOTASSET, TOTASSET2 (including as a proxy for economies of scale), AGE, HHICONT, HHITASSET, FINANCIAL, TECHNICAL, EQUITY, FOREIGN, PUBLIC, EDUC, BINT,



and FINT are employed as independent variables. In this model, AGE, EDUC, and EQUITY are used as control variables.

## Empirical results

This section presents and interprets the empirical findings derived from the estimations of Models I–V. The discussion is structured around three main dimensions: firm-specific characteristics (e.g. size, age, ownership structure), market structure variables (e.g. concentration ratios and competition level), and financial performance indicators (e.g. technical and financial profitability, asset composition). For each dimension, the estimated signs and statistical significance of the coefficients are evaluated in light of the theoretical expectations outlined in earlier sections. In Models I and II, the negative and statistically significant (at the 1% level) coefficient of TOTASSET confirms the expectation that larger firm size is associated with lower technical inefficiency. However, the positive and significant coefficient of TOTASSET2 in the same models suggests a non-linear scale effect, indicating that after a certain threshold, increases in size may reduce efficiency gains. This pattern implies that private pension firms in Türkiye may operate on the diminishing-returns segment of the long-run average cost curve, where managerial slack, coordination costs, and information asymmetries begin to offset the advantages of scale. Such dynamics are consistent with Leibenstein's (1966) concept of X-inefficiency, which attributes internal inefficiency to weakened motivation and ineffective monitoring within large organisations. The negative coefficients of AGE, which are significant at the 5% level, suggest that older firms may operate more efficiently. This may reflect learning-by-doing effects, accumulated managerial experience, and established operational routines that enhance resource utilisation and compliance efficiency. However, a counterargument can be made that older firms may also suffer from bureaucratic inertia and slower adaptation to digital transformation in fund management, which could eventually limit dynamic efficiency gains in the long term. The significance of AGE when TOTASSET is excluded indicates that efficiency improvements stem from organisational experience rather than firm size. AGE captures learning-by-doing, managerial maturity, and operational stability, which enhance efficiency independently of scale effects. Once TOTASSET is removed, these experience-based gains become more evident, suggesting that efficiency in pension firms is driven more by accumulated expertise than by asset expansion.

Regarding market structure, the insignificant coefficient of HHITASSET and the negative and statistically significant (at the 5% level) coefficient of HHICONT in Model IV indicate that pension providers operating in more concentrated contribution markets—where a few large firms account for a greater share of total contributions—tend to be more efficient. This does not imply that funds with fewer individual contributors making larger contributions are more efficient; rather, it reflects that dominant firms in less competitive markets may benefit from scale advantages, better resource allocation, or superior portfolio management. This pattern supports the hypothesis of Hoberg et al. (2018) that less competitive environments can allow managers to exploit strategic advantages and apply superior information-based investment



strategies. However, excessive concentration could also reduce innovation incentives and generate X-inefficiency (Leibenstein 1966) by weakening competitive discipline. Hence, efficiency improvements observed in concentrated markets should be interpreted as context-dependent and possibly reflecting temporary strategic advantages rather than persistent structural superiority (See Table 2 for details).

The role of profitability indicators is also pronounced. The variable FINANCIAL, which measures financial profit as a percentage of assets, consistently exhibits a negative and statistically significant coefficient across all four models, suggesting that financially more profitable firms tend to operate more efficiently, consistent with the theoretical expectation stated in H5. By contrast, TECHNICAL profitability is statistically insignificant in all models, suggesting that high contribution-related costs may erode the efficiency gains from technical operations. Regarding capital structure, the positive and significant (at the 1% level) coefficient of EQUITY in Models I–IV suggests that firms with a higher equity ratio tend to be more inefficient. Ownership structure is also relevant: the PUBLIC variable is negative and only significant at the 10% level with technical inefficiency in Models I–III, supporting the claim that public ownership can contribute to efficiency through enhanced accountability, echoing Jiao and Ye's (2013) findings. Given that the dependent variable measures inefficiency, negative marginal effects indicate improvements in efficiency. For instance, the average marginal effect of FINANCIAL ( $-0.0746$ ) suggests that a one-unit increase in financial profitability reduces inefficiency by approximately 7.5%, whereas AGE ( $-0.0257$ ) implies that each additional year of operation lowers inefficiency by about 2.6%. In contrast, EQUITY ( $+0.045$ ) and FINT ( $+0.03$ ) increase inefficiency, reflecting the inefficiency costs of conservative capitalisation and less liquid assets. The similarity between average and conditional marginal effects confirms that these relationships are robust across both efficient and inefficient firms.

**Table 2** Tobit regression results by coefficient estimates

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0253285***	-0.0270344***		
TOTASSET2	0.0002386**	0.0002451**		
AGE	-0.0162801	-0.0145192	-0.0324209***	-0.0290063**
HHICONT	-6.713825		-10.07072**	
HHITASSET		-0.4762204		-4.90663
FINANCIAL	-0.0939637***	-0.0900912**	-0.0988671***	-0.095468***
TECHNICAL	-0.000000349	-0.000000342	-0.000000356	-0.000000344
EQUITY	0.0551941***	0.0539654***	0.0585535***	0.0567209***
FOREIGN	0.0197806	0.0097071	0.0493247	0.0687841
PUBLIC	-0.3022045*	-0.2845208*	-0.3104352*	-0.2768152
EDUC	0.005127	0.0042124	0.0028994	0.0023918
BINT	0.0044535*	0.0038376	0.0061771***	0.0058335**
FINT	0.0373273*	0.0356742	0.0443676*	0.0438315*

$N=162$

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively



**Table 3** Tobit regression estimates by average marginal effect (dF/dx)

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0201068***	-0.0214508***		
TOTASSET2	0.0001894**	0.0001944**		
AGE	-0.0129238	-0.0115204	-0.0256591***	-0.0229767**
HHICONT	-5.329716		-7.970322**	
HHITASSET		-0.3778629		-3.886686
FINANCIAL	-0.0745923***	-0.071484***	-0.0782468***	-0.075623***
TECHNICAL	-0.000000277	-0.000000271	-0.000000282	-0.000000272
EQUITY	0.0438154***	0.0428195***	0.0463413***	0.0449303***
FOREIGN	0.0157027	0.0077022	0.0390373	0.054486
PUBLIC	-0.2399026*	-0.2257565*	-0.2456893*	-0.2192735
EDUC	0.00407	0.0033424	0.0022947	0.0018946
BINT	0.0035354*	0.003045*	0.0048887***	0.0046209**
FINT	0.029632*	0.0283061	0.0351141*	0.0347202*

N=162

Standard errors in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively

**Table 4** Tobit regression estimates by conditional marginal effect (0<INEFFICIENCY)

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0161438***	-0.0171966***		
TOTASSET2	0.0001521**	0.0001559**		
AGE	-0.0103766	-0.0092357	-0.0202172***	-0.0180395**
HHICONT	-4.279253		-6.279943**	
HHITASSET		-0.3029247		-3.051512
FINANCIAL	-0.0598905***	-0.0573072***	-0.0616519***	-0.0593731***
TECHNICAL	-0.000000223	-0.000000218	-0.000000222	-0.000000214
EQUITY	0.0351796***	0.0343275***	0.036513***	0.0352756***
FOREIGN	0.0126077	0.0061747	0.0307581	0.042778
PUBLIC	-0.1926189*	-0.1809842*	-0.1935825*	-0.1721558
EDUC	0.0032678	0.0026795	0.001808	0.0014875
BINT	0.0028386*	0.0024411*	0.0038519***	0.003628**
FINT	0.0237916*	0.0226924	0.0276669*	0.0272595*

N=162

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively

In terms of asset allocation, the variables BINT (interest-bearing assets) and FINT (interest-free assets) exhibit positive relationships with technical inefficiency in Models I, III, and IV; however, the coefficients of FINT are only marginally significant at the 10% level, indicating limited evidence for this association. Moreover, the marginal effects reported in Tables 3 and 4 indicate that the impact of FINT is



more pronounced than that of BINT, confirming theoretical expectations based on the liquidity management perspective (Li et al. 2020). The higher inefficiency associated with FINT reflects the greater volatility and risk embedded in interest-free instruments, as discussed by Anuno et al. (2024). These results emphasise the importance of risk-adjusted portfolio management for operational performance.

Table 5 presents the estimation results for Model V, which applies the Panzar–Rosse framework to assess the degree of competition in the Turkish private pension fund market. In this specification, the dependent variable LNTPROFIT denotes the natural logarithm of total revenues, serving as a proxy for the profitability of private pension companies. Accordingly, the estimated coefficients represent the elasticities of revenues with respect to input prices. The coefficients of FIXED and PERSON are statistically significant and negatively signed, indicating that increases in fixed and personnel costs are associated with proportionally lower revenues. This suggests that pension fund companies have limited ability to transfer higher costs to consumers through pricing, reflecting the presence of market power and weak price responsiveness. The overall model is statistically significant, as indicated by the F-statistic, and the Histogram test ( $p=0.193$ ) confirms that the residuals are normally distributed, demonstrating the robustness of the estimation. The H-statistic, calculated as the sum of the elasticities of input prices (FIXED+PERSON+COM), is estimated at  $-0.98$ , which, according to the Panzar–Rosse interpretation, indicates the presence of a monopolistic or collusive market structure; moreover, the related null hypotheses further clarify the competitive setting—specifically, the null of perfect competition ( $H=1$ ) is strongly rejected ( $p=0.0000$ ), the null of monopolistic competition ( $H\geq 0$ ) is also rejected ( $p=0.0000$ ), while the null of monopoly or collusion ( $H\leq 0$ ) cannot be rejected ( $p=0.9999$ ), consistently confirming that the market operates under a collusive or monopolistic structure rather than monopolistic competition.

To ensure the validity and reliability of the estimation results given the moderate sample size, several robustness analyses were conducted for both the Tobit and Panzar–Rosse models. For the Tobit estimations, the models were re-estimated using

**Table 5** Panzar–Rosse model estimation results

OLS estimates	
Dependent variable: LNTPROFIT	
FIXED	-0.1544555**
PERSON	-0.9850205***
COM	0.1592195
EQUITY	-0.15606
R <sup>2</sup>	0.4364
F-statistic (Prob.)	0.0000***
Histogram Test (Prob.)	0.1930
H-statistic	-0.9802
$p$ -value null ( $H=0$ )	0.0000***
$p$ -value null ( $H\leq 0$ )	0.9999
$p$ -value null ( $H\geq 0$ )	0.0000***

In the OLS estimation, robust standard errors are utilised

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively



heteroskedasticity-robust standard errors to correct for potential violations of the homoskedasticity and normality assumptions. The results reported in Tables 15, 16 and 17 show that the signs, magnitudes, and levels of statistical significance remain virtually unchanged, confirming that the main inferences are not driven by error distribution assumptions or limited sample bias. Regarding the Panzar–Rosse model, additional estimations were carried out using robust regression to reduce the influence of potential outliers. Moreover, both log-linear and log-log functional specifications of the revenue equation were tested to evaluate the sensitivity of the estimated H-statistic to model specification. As presented in Tables 18 and 19, the log-linear model provided the most consistent and theoretically coherent results, while the log-log specification produced comparable but stable coefficients. As a result, the coefficient signs and significance levels remain stable, indicating that neither outliers nor alternative model structures materially affect the conclusions.

In Figs. 1 and 2; Table 6, the concentration analysis based on total asset market share further clarifies the competitive structure of the Turkish private pension market. The HHI values range between 1134 and 1505 during 2013–2022, indicating a moderately concentrated market. Similarly, the four-firm concentration ratio ( $CR_4$ ) fluctuates between 61.4% and 71%, suggesting that a small number of firms dominate total contributions. These results are consistent with a moderately concentrated, oligopolistic market structure, rather than a pure monopoly or cartel. Overall, these findings point to a collusive oligopoly, characterised by structural concentration rather than explicit collusion, aligning with the negative and significant H-statistics observed in the regression models.

The empirical findings largely confirm the theoretical expectations outlined in the hypotheses. The negative coefficient of firm size and the positive sign of its squared term confirm H1, indicating that efficiency increases with firm size up to an optimal scale, after which diseconomies of scale emerge. The negative and significant coefficients of firm age validate H2, suggesting that older firms benefit from accumulated experience and organisational learning. Regarding market structure, the negative

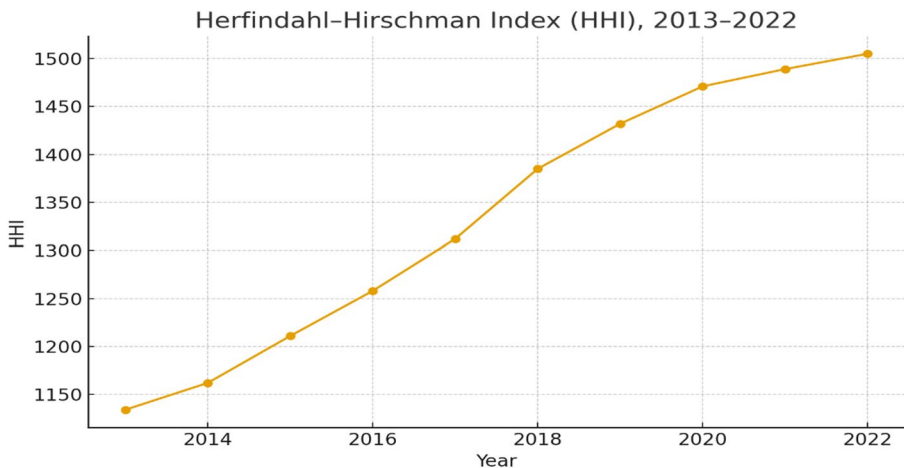
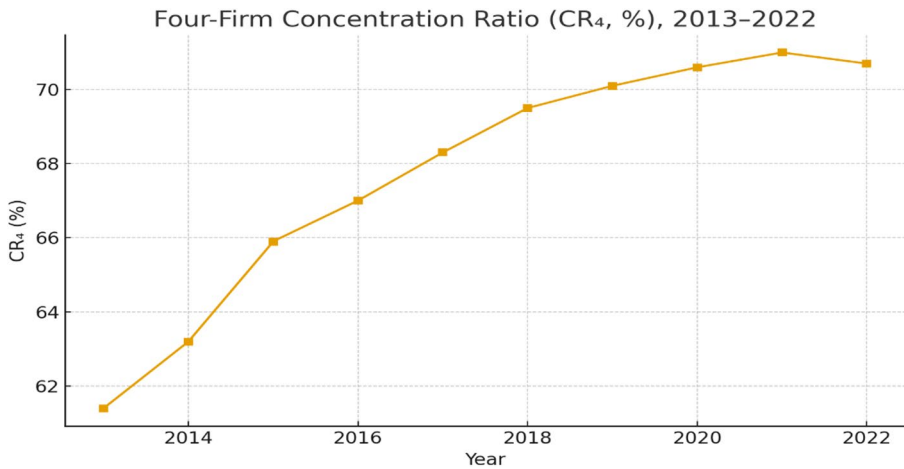


Fig. 1 Herfindahl–Hirschman Index (HHI) in the Turkish private pension fund market (2013–2022)





**Fig. 2** Four-firm concentration ratio (CR<sub>4</sub>, %) in the Turkish private pension fund market (2013–2022)

**Table 6** Market concentration in the Turkish private pension fund market (2013–2022)

Year	Herfindahl–Hirschman index (HHI)	Four-firm concentration ratio (CR <sub>4</sub> , %)
2013	1134	61.4
2014	1162	63.2
2015	1211	65.9
2016	1258	67.0
2017	1312	68.3
2018	1385	69.5
2019	1432	70.1
2020	1471	70.6
2021	1489	71.0
2022	1505	70.7

coefficient of the concentration index (HHICONT) provides partial support for H3, implying that lower competition (higher concentration) enhances efficiency, consistent with the stability and information advantages of dominant firms. The positive and significant impact of foreign and public ownership supports H4, highlighting the role of managerial expertise and governance quality in improving efficiency. The positive coefficients of financial and technical profitability confirm H5, indicating that financially stronger firms operate more efficiently. The coefficients of interest-bearing and interest-free assets support H6, revealing that portfolios with higher shares of interest-bearing instruments are associated with greater efficiency, while reliance on interest-free assets reduces it. Finally, the Panzar–Rosse H-statistic yields a value below 1 but above 0, confirming H7 and indicating that the Turkish private pension market operates under monopolistic competition, where firms compete in a differentiated but imperfectly competitive environment.



## Conclusion

In light of the study's findings, several conclusions are drawn regarding the private pension market and the determinants of efficiency in private pension companies in Türkiye. The performance of private pension funds is critical, as it directly impacts the income and living standards of the elderly population. Efficient fund management, particularly in terms of liquidity, plays a vital role in ensuring the efficiency and sustainability of private pension companies. This study reveals that both interest-bearing and interest-free financial assets have a negative effect on technical efficiency. Notably, interest-free assets, due to their risky nature, have a more pronounced impact on technical inefficiency compared to interest-bearing financial assets. Contrary to some theoretical perspectives suggesting the existence of economies of scale, the study does not confirm that larger pension funds inherently benefit from economies of scale. The evidence suggests that private pension firms in Türkiye may face diminishing returns to scale, where excessive expansion creates managerial and coordination challenges that offset operational gains—an outcome consistent with Leibenstein's (1966) concept of X-inefficiency. Firm age also emerges as a key determinant of efficiency. Older firms tend to be more efficient, likely due to accumulated experience, organisational learning, and established managerial routines. However, these advantages may be counterbalanced by slower adaptation to digital transformation and innovation. The Turkish private pension market is characterised by a collusive oligopoly structure, which impacts competition levels and technical efficiency. The findings suggest that less competition may allow fund managers to better utilise their skills and investment opportunities. Yet, excessive concentration risks undermining innovation incentives and fostering X-inefficiency by weakening competitive pressure.

Overall, the study underscores that efficiency in Türkiye's private pension market is shaped by the intricate interaction of firm-specific characteristics, market concentration, and asset composition. Therefore, a comprehensive policy approach should simultaneously foster managerial and technological innovation to mitigate X-inefficiency in large and mature firms, ensure a balanced competitive environment that supports both efficiency and innovation, and promote diversified investment frameworks that enhance the performance of both conventional and interest-free financial assets. Through such an integrated approach, policymakers can strengthen the overall efficiency and resilience of the private pension system while ensuring its long-term contribution to the financial well-being of retirees.

## Appendix

See Tables 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19.



**Table 7** List of private pension companies analysed

Company	Years included in the analysis
Aegon Pension and Life Company	2013–2021
Agesa Pension and Life Company	2021–2022
Allianz Life and Pension Company	2013–2022
Anadolu Life and Insurance Company	2013–2022
Avivasa Pension and Life Company	2013–2020
AXA Life and Insurance Company	2013–2022
Bereket Pension and Life Company	2017–2022
BNP PARIBAS CARDIF	2013–2022
Cigna Finans Pension and Life Company	2013–2019
Cigna Sağlık Life and Insurance Company	2020–2022
Fiba Pension and Life Company	2013–2022
Garanti Pension and Life Company	2013–2022
Groupama Pension Company	2013–2017
Halk Life and Insurance Company	2013–2019
ING Pension Company	2013
Katılım Pension and Life Company	2014–2022
Metlife Pension and Life Company	2013–2022
NN Life and Insurance Company	2014–2022
Türkiye Life and Insurance Company	2020–2022
Vakıf Pension and Life Company	2013–2019
Ziraat Life and Insurance Company	2013–2019



**Table 8** Summary of empirical literature on pension fund efficiency, ownership, and regulation

Author(s), year	Country/period	Methodology	Key focus	Main findings
Seran et al. (2023)	Indonesia, 2011–2017	Two-stage Network DEA	Investment and operational efficiency	Investment efficiency is the main driver of overall efficiency
Tang and Mitchell (2008)	U.S., 1998–2002	Probit	Fund menu design	Fund types significantly affect efficiency of defined contribution plans
Alda and Ferruz (2012)	Spain, 1999–2010	OLS	Fees, fund performance	High management fees lower fund efficiency
Yan and Foong (2021)	Asia (5 countries), 6 years	OLS	Fees, returns	Asian funds underperform compared to the market; fees have negative impact
Barros and Garcia (2006, 2007)	Portugal, 1994–2003	DEA, Stochastic Frontier	Scale, privatisation, labour cost	Scale and mergers improve efficiency; cost structure is decisive
Mazreku et al. (2020)	Balkans (3 countries)	Regression (FE, RE, Hausman–Taylor)	GDP, ROI, contributions	Macroeconomic indicators positively affect performance
Guillen (2008)	Latin America (10 countries)	DEA & OLS	Rate of return vs. efficiency	Efficiency differs by country; linked to local economic benefits
Jiao and Ye (2013)	U.S., 1985–2005	Panel regression	Public pension fund ownership	Moderate ownership increases firm value; excessive ownership harms it
Mfoutou and Danquah (2022)	Republic of Congo, 2011–2020	DEA-adjusted estimator	Private vs. public pension plans	Private sector more cost-efficient than public sector
Kurtaran et al. (2013)	Türkiye, 2004–2011	DEA	Firm size, ownership	Large and domestic firms less efficient than small and foreign ones
Gökçen et al. (2020)	Türkiye, 2003–2014	Pooled OLS	Bank affiliation, incentives	Bank-affiliated funds underperform compared to independent ones
Lin and Lu (2024)	Taiwan, 2008–2020	Dynamic Network DEA	Ownership structure	Private managers outperform state-owned funds
Antolin (2008a, b)	OECD & Latin America	Sharpe ratio	Regulatory restrictions	Restrictions lower performance; reforms improve efficiency
Mitkova and Mlynarovič (2020)	Slovakia, 2005–2009	Efficient frontier (CVaR–return)	Legislative changes	Regulation strongly affects investment decisions
Erzurumlu and Ucardağ (2021)	Türkiye, 2011–2019	Panel data (FE, RE, Within-Between)	Regulation, costs	Regulatory change shifted investor focus from returns to costs
Demir et al. (2020)	Türkiye, 2017	Grey Relational Analysis	Firm performance ranking	Garanti, Anadolu, and Allianz show highest efficiency
Çamlıbel (2022)	Türkiye, 2015–2019	SD & MARCOS	Ranking comparison	SD method yields higher consistency; Garanti and Ziraat lead
Durgut (2022)	Türkiye, 2015–2020	SWARA–SD–MAIRCA	Multi-criteria evaluation	Garanti most efficient; Aegon least efficient



**Table 8** (continued)

Author(s), year	Country/period	Methodology	Key focus	Main findings
Gurol and Imam (2018)	Türkiye, 2006–2016	TOPSIS	Multi-criteria decision	Efficiency varies; peak in 2008, lowest in 2006
Demirtaş and Keçeci (2020)	Türkiye, 2013–2016	DEA	Temporal efficiency	Efficiency improves when inter-period effects are included

**Table 9** Summary of empirical studies on market competition in pension fund markets

Author(s), Year	Country/Period	Methodology	Focus/Variables	Main findings
Hastings et al. (2017)	Mexico, 1997–2007	Structural logit & equilibrium simulation	Impact of sales force on price sensitivity and fund fees	Exposure to sales agents reduces price sensitivity, weakens competition, and increases fees. Policy simulations (price caps, financial literacy) improve outcomes
Sepúlveda (2012)	Chile, 1996–2008	Panzar–Rosse (H-statistic)	Degree of competition among PFAs; market concentration	Negative and significant relationship between concentration and competition; industry resembles a cartel/monopoly structure



**Table 10** Empirical studies on economies of scale in pension funds

Author(s), year	Country/period	Methodology	Focus/variables	Main findings
Mama et al. (2011)	South Africa, 1996–2006	OLS, SUR	Economies of scale and scope; DB vs. DC plans	Significant economies of scale but not of scope. Defined benefit plans more efficient than defined contribution plans
Bikker and de Dreu (2009)	Netherlands, 1992–2004	Regression analysis	Operating cost efficiency	Scale significantly reduces operating costs; large funds have cost advantages.
Broeders et al. (2016)	Netherlands, 2013	Regression, cost decomposition	Investment cost structure by asset class	Economies of scale in fixed income, equity, and commodities; no scale effects in real estate or private equity.
Agostini et al. (2012)	Chile, 1994–2012	Regression	Economies of scale and scope	Chilean pension funds show both scale and scope economies.
Higgs and Worthington (2012)	Australia, 2011	Regression	Fund size and efficiency	Large pension funds display significant scale economies
Alserda et al. (2018)	Netherlands, 1992–2013	Stochastic cost frontier, cost elasticity	Administrative vs. investment cost efficiency	Large economies of scale in administration; modest diseconomies in investment functions
Bikker & Meringa (2022)	Netherlands, 2012–2019	Panel regression	Cost margins and portfolio efficiency	Inconclusive evidence for scale benefits; large funds' cost advantages offset by performance fees
Bikker & Meringa (2024)	Netherlands, 2007–2022	Panel regression	Cost ratios, diversification, hedging	Larger funds have lower cost ratios but do not outperform smaller funds due to high fees and weak hedging



**Table 11** Descriptive statistics for models I-IV

	INEFFICIENCY	BINT	AGE	EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHI-TAS-SET	PUB-LIC	TECHNI-CAL	TOTAS-SET	EDUC
Mean	0.6940	15.2240	7.0123	9.0605	1.5834	0.4630	0.6358	0.1358	0.1248	0.1852	48905.26	9714465	75.5586
Me- dian	0.6485	7.5423	6.5	6.7233	1.0473	0	1	0.1331	0.1187	0	12181.54	3364203	78.8250
Max- imum	2.5148	186.1025	19	69.1801	8.9915	20.7879	1	0.1484	0.1504	1	2860875	112000000	95.8904
Mini- mum	0	0.0774	1	0.6886	0.1049	0	0	0.1202	0.1127	0	0.0000114	14947.63	14.0625
Std. Dev.	0.6384	22.3971	4.5927	8.3663	1.5219	2.025795	0.4827	0.0099	0.0130	0.3896	234879.5	17076746	12.7241
Ob- serva- tions	162												



**Table 12** Descriptive statistics for model V

	LNTPROFIT	LNPERSON	LNEQUITY	LNFIXED	LNCOM
Mean	11.5501	-5.1783	-2.6922	-6.3827	-4.1316
Median	11.2829	-5.4136	-2.6863	-6.4038	-4.0433
Maximum	14.9330	-0.7694	1.8	7.2919	0.5375
Minimum	8.8761	-7.0190	-4.9783	-10.7497	-9.1367
Std. Dev.	0.9698	1.1145	0.8889	1.61890	1.3517
Observations	162				



Table 13 Correlation matrix for variables in models I-IV

	BINT	AGE	EDUC	EFFICIENCY	EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
		AGE	EDUC	EFFICIENCY	EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
			EDUC	EFFICIENCY	EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
				EFFICIENCY	EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
					EQUITY	FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
						FINANCIAL	FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
							FINT	FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
								FOREIGN	HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
									HHICONT	HHITASSET	PUBLIC	TECHNI-	TOTAS-
										HHITASSET	PUBLIC	TECHNI-	TOTAS-
											PUBLIC	TECHNI-	TOTAS-
												TECHNI-	TOTAS-
													TOTAS-
													SET
BINT	1												
AGE	-0.0724	1											
EDUC	0.0812	0.1827	1										
EFFI-	0.1187	0.2124	0.1804	1									
CIEN-					1								
CY						1							
EQ-	0.2563	-0.3371	-0.1771	-0.0263		0.4246							
UITY							1						
FI-	0.3427	-0.2192	-0.0321	0.1738		0.4246							
NAN-								1					
CIAL									1				
FINT	0.1367	0.1088	0.1535	0.0576		-0.0842							
FOR-	-0.0275	-0.2109	-0.2032	-0.1178		0.0427							
EIGN							1						
HHI-	0.1699	-0.0036	0.2664	0.0669		0.0427							
CONT								1					
HHI-	0.1269	0.2220	0.3751	0.1227		0.1160							
TAS-									1				
SET										1			
PUB-	0.1891	-0.1332	0.0643	0.0305		0.0427							
LIC											1		
TECH-	0.1264	-0.2215	0.1043	-0.0615		0.0427							
NI-												1	
CAL													1
TO-	-0.1966	0.2787	0.2999	0.2761		0.0484							
TAS-													1
SET													



**Table 14** Correlation matrix for variables in model V

	LNTPROFIT	LNPERSON	LNEQUITY	LNFIXED	LNCOM
LNTPROFIT	1	-0.5276	-0.1602	-0.2908	-0.2734
LNPERSON	-0.5276	1	0.5223	0.4842	0.6599
LNEQUITY	-0.1602	0.5223	1	0.4129	0.4727
LNFIXED	-0.2908	0.4842	0.4129	1	0.4373
LNCOM	-0.2734	0.6599	0.4727	0.4373	1

**Table 15** Tobit regression results: coefficient estimates with robust standard errors

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0253285***	-0.0270344***		
TOTASSET2	0.0002386**	0.0002451**		
AGE	-0.0162801	-0.0145192	-0.0324209**	-0.0290063**
HHICONT	-6.713825		-10.07072**	
HHITASSET		-0.4762204		-4.90663
FINANCIAL	-0.0939637***	-0.0900912***	-0.0988671***	-0.095468***
TECHNICAL	-0.000000349	-0.000000342	-0.000000356	-0.000000344
EQUITY	0.0551941***	0.0539654***	0.0585535***	0.0567209***
FOREIGN	0.0197806	0.0097071	0.0493247	0.0687841
PUBLIC	-0.3022045*	-0.2845208	-0.3104352*	-0.2768152
EDUC	0.005127	0.0042124	0.0028994	0.0023918
BINT	0.0044535*	0.0038376**	0.0061771***	0.0058335**
FINT	0.0373273*	0.0356742	0.0443676	0.0438315*

N= 162

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively



**Table 16** Tobit regression estimates: average marginal effect (dF/dx) with robust standard errors

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0201068***	-0.0214508***		
TOTASSET2	0.0001894**	0.0001944**		
AGE	-0.0129238	-0.0115204	-0.0256591**	-0.0229767**
HHICONT	-5.329716		-7.970322**	
HHITASSET		-0.3778629		-3.886686
FINANCIAL	-0.0745923***	-0.071484***	-0.0782468***	-0.075623***
TECHNICAL	-0.000000277	-0.000000271	-0.000000282	0.000000272
EQUITY	0.0438154***	0.0428195***	0.0463413***	0.0449303***
FOREIGN	0.0157027	0.0077022	0.0390373	0.054486
PUBLIC	-0.2399026*	-0.2257565	-0.2456893*	-0.2192735
EDUC	0.00407	0.0033424	0.0022947	0.0018946
BINT	0.0035354*	0.003045***	0.0048887***	0.0046209***
FINT	0.029632*	0.0283061	0.0351141	0.0347202

N=162

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively

**Table 17** Tobit regression estimates: conditional marginal effect ( $0 < \text{INEFFICIENCY}$ ) with robust standard errors

Independent variable	Dependent variable: INEFFICIENCY			
	Model			
	Model I	Model II	Model III	Model IV
TOTASSET	-0.0161438***	-0.0171966***		
TOTASSET2	0.0001521**	0.0001559**		
AGE	-0.0103766	-0.0092357	-0.0202172**	-0.0180395**
HHICONT	-4.279253		-6.279943**	
HHITASSET		-0.3029246		-3.051512
FINANCIAL	-0.0598905***	-0.0573072***	-0.0616519***	-0.0593731***
TECHNICAL	-0.000000223	-0.000000218	-0.000000222	-0.000000214
EQUITY	0.0351796***	0.0343275***	0.036513***	0.0352756***
FOREIGN	0.0126077	0.0061747	0.0307581	0.042778
PUBLIC	-0.1926189*	-0.1809842	-0.1935825*	-0.1721558
EDUC	0.0032678	0.0026795	0.001808	0.0014875
BINT	0.0028386***	0.0024411***	0.0038519***	0.003628***
FINT	0.0237916*	0.0226924	0.0276669*	0.0272595*

N=162

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively



**Table 18** The Panzar–Rosse model Estimation results using robust regression

OLS estimates	
<i>Dependent variable: LNTPROFIT</i>	
FIXED	-0.1499892**
PERSON	-1.020108***
COM	0.131989
EQUITY	-0.1197829
F-statistic (Prob.)	0.0000***
Histogram Test (Prob.)	0.1366
H-statistic	-1.0381082
<i>p</i> -value null ( $H=0$ )	0.0000***
<i>p</i> -value null ( $H\leq 0$ )	0.9999
<i>p</i> -value null ( $H\geq 0$ )	0.0000***

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively

**Table 19** The Panzar–Rosse model estimation results using robust regression

OLS estimates	
<i>Dependent variable: LNTPROFIT</i>	
LNFIXED	-0.640046**
LNPERSON	-4.519515***
LNCOM	0.4369562
LNEQUITY	-0.6842108
F-statistic (Prob.)	0.0000***
Histogram Test (Prob.)	0.0623
H-statistic	-4.7226048
<i>p</i> -value null ( $H=0$ )	0.0000***
<i>p</i> -value null ( $H\leq 0$ )	0.9999
<i>p</i> -value null ( $H\geq 0$ )	0.0000***

The variables LNFIXED, LNPERSON, LNCOM, and LNEQUITY represent the natural logarithmic transformations of the FIXED, PERSON, COM, and EQUITY variables, respectively

Standard errors are in parentheses

\*\*\*, \*\*, and \* indicate that the statistical values are significant at 1%, 5%, and 10%, respectively



**Acknowledgments** During the preparation of this study, the authors used the Chat GPT/Open AI in order to support the editing of academic English. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the article.

**Funding** Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK).

**Data Availability** The data used in this study were obtained from the Insurance and Private Pension Regulation and Supervision Authority and the Insurance Association of Türkiye. These data are publicly available at the following link: <https://www.seddk.gov.tr/tr/raporlar/sigorta-reasurans-ve-emeklilik-sirketlerin-in-mali-tablolari>

## Declarations

**Conflict of interest** None.

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**Assist. Prof. Dr. Can Verberi** Can Verberi holds a bachelor's degree in economics from Yıldız Technical University and Master's and PhD degrees in the same field from Istanbul University. He completed his PhD thesis titled "An Evaluation of the Turkish Private Pension System in Terms of Its Effects on Income Inequality Among Elderly Households' Savings and Funds Performance" in 2024. He has conducted research in the field of financial economics. Currently, he is an Assist. Prof. PhD. at Sırnak University.

**Prof. Dr. Muhittin Kaplan** Muhittin Kaplan is currently a professor of economics at Ibn Haldun University. He earned his Ph.D. in Economics from the University of Leicester in the United Kingdom (1998–2003), where his doctoral dissertation, titled "An Econometric Analysis of Economic Reform in Turkey: Industrial Policy and Changing Structure". Prior to doctoral studies, Dr. Kaplan obtained his Master's degree from the University of Leicester (1996–1997), and undergraduate degree in Economics from Marmara University, Türkiye.

**Prof. Dr. Mehmet Kutluğhan Savaş Ökte** Mehmet Kutluğhan Savaş Ökte earned his bachelor's, master's, and PhD degrees in economics from Istanbul University. He completed his PhD on the interaction between the real and financial sectors within macroeconomic theory. His research focuses on economic policy, financial crises and labor economics. He has published in national and international journals and contributed to edited volumes on Turkish economic history and institutional change. He currently serves as a Professor of Economics at Istanbul University.

