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Article

Integrating panel data regression and fuzzy decision-making approaches to evaluate the impact of currency-hedged deposits on participating banks

Selman Duran[1], Serkan Eti[2]*, Serhat Yüksel[1], Hasan Dinçer[1]

[1]The School of Business, İstanbul Medipol University, İstanbul, Turkey
[2]IMU Vocational School, İstanbul Medipol University, İstanbul, Turkey

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*Corresponding author
Email address:
serhatyuksel@medipol.edu.tr

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ABSTRACT

Currency-Hedged Deposits (CHD) were introduced in Türkiye to hedge the currency risk. Hence, it is aimed to provide macroeconomic stability in this country. Nevertheless, the impact of this implication on banks' participation is unclear. This study analyzes the impact of the foreign exchange hedge deposit (CHD) mechanism on the financial performance of participation banks in Türkiye. This study integrates fuzzy multi-criteria decision-making analysis with panel data regression. In this framework, data from these banks for 2021-2023 is considered. First, panel regression analysis is conducted for six participating banks. Second, a Euclidean distance-based CIMAS technique is used to find the most critical criteria. For this purpose, Fermatean fuzzy numbers are considered in this modelling process to handle uncertainties more effectively. The main contribution of this research is the hybrid consideration of panel data regression and fuzzy decision-making analysis. Owing to this combination, the impact of this new implication on bank participation can be more effectively identified. Econometric results indicate that CHD has a positive impact on profitability. On the other hand, risk management and compatibility with interest-free financing are the most critical factors.

1. Introduction

This study examines the effects of this implementation on the financial performance of participation banks in Turkey [1]. In the studies, the factors affecting banks' financial performance are evaluated along two dimensions [2]. The first group includes macro-level factors such as inflation rate, interest rate, gross national product, and industrial production, while internal factors include total loans/total assets, asset size, equity/total assets, non-performing loans/total loans, personnel expenses/total revenues, off-balance sheet activities/total assets, and bank type. In addition to these variables, this study predicts that currency-hedged deposits, as a macro factor, also affect financial performance [3]. The primary aim of this study is to comprehensively examine the impact of the Currency-Hedged Deposit (CHD) practice on the financial performance and strategic sustainability of participation banks in Turkey by integrating econometric modeling with fuzzy decision-making techniques. Existing studies mostly focus on the macroeconomic impacts of the CHD. However, there are few studies in the literature that address which factors are most critical. This study integrates panel data econometric analysis with a fuzzy decision-making model to address this issue. The hybrid approach provides a more comprehensive understanding of the dual impact of the CHD. Furthermore, it also provides a replicable methodological framework for future analyses of Islamic financial innovations. This study's analysis process involves two distinct stages. First, a panel regression analysis is conducted for six different participation banks. Data from 2021 to 2023 are considered. In this framework, return on assets (ROA) and return on equity (ROE) are used as dependent variables. Furthermore, factors such as exchange rate volatility and inflation rates are integrated into the model as independent variables. Second, a new fuzzy decision-making model aims to identify the most critical criteria. In this process, the CIMAS technique, based on Fermatean fuzzy numbers and Euclidean distance, is integrated.

2. Literature review

The scope of the study conducted by Kaya [4] comprises legal entities that benefit from the Currency Protected TL Time Deposit Account. In the study, it is aimed to reveal the accounting records that should be made at the end of the period, at the opening and closing of the account at the end of the period by the enterprises that convert their foreign currencies in US Dollars, Euros and British Pounds in their balance sheet as of 31.12.2021 until the date of submission of

the declaration regarding the fourth provisional tax period, with a comprehensive sample application. It is expected that the study will contribute to the businesses and accounting professionals who open or want to open Foreign Currency Conversion Currency Hedged TL Time Deposit Account. In the survey conducted by Yayman [5], the question is examined whether the tax privileges granted to the exchange rate-protected deposit system cost the state budget. As a result, it was found that the conditional obligation undertaken by the public sector gives confidence to residents to protect the financial value of the TL, it is not yet possible to determine the net return guarantee provided to Turks living abroad, budget expenditures have increased over the period analyzed, but budget revenues have increased almost at the same level, the primary surplus has increased, so its impact on the budget has not yet been low, the cost of the increase in exchange rate-protected deposit accounts is gradually increasing and the main risk is unforeseen jumps in the exchange rate.

In the study by Akgemci [6], it is stated in this announcement that the currency-hedged deposit account is a financial asset and should be measured at fair value through profit or loss within the scope of TFRS 9 Financial Instruments Standard. In this regard, it is discussed how to classify related deposit accounts within the scope of TFRS 9, how to measure the end-of-period, and how to recognize income or expenses arising after a company subject to an independent audit converts its forward foreign currency accounts into PPDCs. Kaldırım and Selvi [7] explained the legal structure of FX-hedged time deposit accounts. The accounting and reporting principles within the framework of the Uniform Accounting System, TFRS-9, and US GAAP ASC 815 are examined in different exchange rate scenarios using an example, and financial reports are compared. In addition, the differences in the provisions of US GAAP ASC-815 and TFRS-9 related to embedded derivatives are presented. Álvarez-Díez et al. [8] considered a multi-currency cross-hedging strategy that minimizes currency risk. They measured the reduction in foreign exchange risk carried using natural multi-currency cross hedging, using the Conditional Value at Risk (CVaR) and Value at Risk (VaR) to measure market risk rather than variance. CVaR is minimized using linear programming, while a multi-objective genetic algorithm is designed to mitigate VaR across two scenarios for each currency. The results show that the optimal hedging strategy that minimizes VaR is different from the minimum CVaR hedging strategy. Another point is that significant reductions in VaR and CVaR can be achieved by investing only in other currencies.

Du et al. [9] investigated differences between fully hedged and unhedged portfolios comprising 10 different risky asset datasets from 2006 to 2014. Empirical results show that fully hedged portfolios have significantly higher Sharpe ratios than unhedged portfolios. In terms of economic utility, a risk-averse investor would be willing to pay more per year to build a fully hedged portfolio. For example, investors using the equal-weighted portfolio strategy are willing to pay more than 7.2% and 3.3% per annum to hedge RMB exchange rate risk in CNY and CNH, respectively. Moreover, based on the results in sub-periods and time-varying rolling forecasts, we conclude that hedging currency risk in portfolio management will become increasingly important during RMB internationalization. Bag and Omrane [10] tested the statistical relationship between CSR and corporate financial performance (CFP) of the top 100 companies listed on the National Stock Exchange (NSE) in India. Factor analysis and multivariate regression were conducted, yielding conclusive findings on the CSR-CFP relationship. Overall, the existing literature on Currency-Hedged Deposits (CHD) can be grouped into three main strands: (1) studies emphasizing accounting and regulatory issues, (2) macroeconomic assessments focusing on budgetary and fiscal effects, and (3) international works examining currency risk and hedging efficiency. However, there are limited studies that have focused on the most effective determinants.

3. Proposed methodology

In the first stage, we conducted a panel data regression analysis to examine the relationship among the variables. After that, a decision-making model is generated to find the most significant criteria.

3.1 Panel data regression methodology

Panel data is a data structure created by systematically observing units (horizontal cross-section) such as people, firms, and countries within a specified period (vertical cross-section) [11]. With this data group, the number of observations increases by including both time series of periods and variables of units in the models [12]. Thus, panel data provides richer explanatory data, more variability, more degrees of freedom, and more efficiency, while reducing the linearity between variables [13]. Panel data regression, unlike time series, can be shown as [14]:

$$y_{i,t}= \alpha+X'_i, t\beta+ u_{i,t} \qquad i=1, \ldots, N, t=1, \ldots, T \tag{1}$$

$$u_{i,t}= \mu i+ v_i, tu_{i,t}= \mu_i+ v_{i,t} \tag{2}$$

In formula (2) μ_i denotes the unit-specific unobservable effect and $v_{i,t}$ is the residual distortion. For example, in a performance analysis equation in finance, $y_{i,t}$ measures the profitability of the business, while $X'_{i,t}$ may include several variables such as firm size, age, sector, region, etc. It is worth noting that μ_i is time-invariant and considers any unit-specific effects not included in the regression. The remaining distortion $v_{i,t}$, varies by unit and time and can be considered as the usual distortion in the regression. Alternatively, for a production function using data on firms over time, $y_{i,t}$ will measure output, and $X'_{i,t}$ will measure inputs. Unobserved firm-specific effects will be captured by μ_i, which can be thought of as unobserved entrepreneurial or managerial skills of firm managers.

As a result, while panel data can address some of the problems faced by time-series or cross-sectional studies, it is not sufficient to eliminate all difficulties. Panel data analyses fall into two main categories of models, depending on the assumptions about the period and individual effects in the error term structure: the one-way error regression model and the two-way random effects model. These models include the fixed-effects and random-effects models. The correlation between individual effects and independent variables is important in the decision process of choosing a model. If there is a correlation between the independent variables and the individual's error term, and if there is a specific sample treatment, the fixed effects model may be preferred. Otherwise, a random effects model would be more appropriate. These models represent the fundamental structures used in panel data analysis. The correct choice of the model is important for the accuracy and reliability of the analysis.

Although the panel data framework helps control for unobservable heterogeneity across banks, potential endogeneity between the currency-hedged deposit variable and financial performance indicators cannot be ruled out entirely. For instance, higher-performing participation banks

might attract larger CHD inflows, while CHD growth itself could influence performance through liquidity and profitability channels. To mitigate this possible simultaneity bias, the models were estimated using lagged explanatory variables as robustness checks. In future research, instrumental variable approaches could further enhance causal inference and address remaining endogeneity concerns.

3.2 Proposed fuzzy decision-making model

This section concerns the formulation of Euclidean distance-based CIMAS using Fermatian fuzzy sets. Thus, while uncertainty is minimized by using fuzzy sets, expert weights are obtained with Euclidean distance-based expert weighting to make the criteria weights more realistic with CIMAS. Prioritizing experts solely by years of experience is unrealistic. Therefore, prioritizing experts requires analyzing other information beyond only their years of experience. For this purpose, the Euclidean distance-based experts' weighting method with CIMAS, as described in the literature [15], is used in this manuscript. The method's steps are as follows. To obtain the important priorities of the experts, the matrix in Equation (3) is constructed with some information from the experts [16].

$$X = \left[x_{ij}\right]_{e\times v} \tag{3}$$

where the columns are v variables containing the age, years of total experience, industry experience, manager experience, and information on patents or certificates e experts. Then, the arithmetic means and standard deviation values of columns are established for computing z-score values using Equations (4) and (5), respectively.

$$\bar{x}_j = \frac{1}{e}\sum_{i=1}^{e} x_{ij} \tag{4}$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{e}\left(x_{ij}-\bar{x}_j\right)^2}{e}} \tag{5}$$

With the help of these statistical values, a standardized matrix is obtained by Equation (6).

$$z_{ij} = \frac{x_{ij}-\bar{x}_j}{\sigma_j} \tag{6}$$

Afterwards, the negative values are determined via Equation (7).

$$neg_j = \min_i z_{ij} \tag{7}$$

Euclidean distances between experts and negative values are calculated with the help of Equation (8).

$$D_i = \sqrt{\sum_{j=1}^{v}\left(z_{ij} - neg_j\right)^2} \tag{8}$$

Finally, the scores of experts are defined by normalizing the distances via Equation (9).

$$E_i = \frac{D_i}{\sum_{i=1}^{e} D_i} \tag{9}$$

A Fermatean fuzzy set (A) is described as Equation (10).

$$A = \{u, \langle \mu_A(u), \nu_A(u)\rangle : u \in U\} \tag{10}$$

Where U is the universe of discourse. μ and ν are named as membership and non-membership degrees, respectively, and between zero and one. These degrees have the condition in Equation (11).

$$0 \le \left(\mu_A(u)\right)^3 + \left(\nu_A(u)\right)^3 \le 1 \tag{11}$$

Moreover, the degree of indeterminacy is identified as Equation (12).

$$\pi_A(u) = \sqrt[3]{1 - \left(\left(\mu_A(u)\right)^3 + \left(\nu_A(u)\right)^3\right)} \tag{12}$$

Consider that A and B are two Fermatean fuzzy sets and β is a positive real number. Then, basic operators are defined in Equations (13) – (16).

$$A + B = \left(\sqrt[3]{\mu_A^3 + \mu_B^3 - \mu_A^3\mu_B^3}, \nu_A\nu_B\right) \tag{13}$$

$$A \times B = \left(\mu_A\mu_B, \sqrt[3]{\nu_A^3 + \nu_B^3 - \nu_A^3\nu_B^3}\right) \tag{14}$$

$$\beta A = \left(\sqrt[3]{1-(1-\mu_A^3)^{\beta}}, \nu_A^{\beta}\right) \tag{15}$$

$$A^{\beta} = \left(\mu_A^{\beta}, \sqrt[3]{1-(1-\nu_A^3)^{\beta}}\right) \tag{16}$$

For example, $(.9,.1) + (.7,.2) = \left(\sqrt[3]{.9^3 + .7^3 - .9^3 * .7^3}, .1 * .2\right)$; $(.9,.1) \times (.7,.2) = \left(.9 * .7, \sqrt[3]{.1^3 + .2^3 - .1^3 * .2^3}\right)$; $2\,(.9,.1) = \left(\sqrt[3]{1-(1-.9^3)^2}, .1^2\right)$

The score and accuracy functions are defined using Equations (17) and (18), respectively.

$$score(A) = \frac{1+(\mu_A)^3-(\nu_A)^3}{2} \tag{17}$$

$$acc(A) = (\mu_A)^3 + (\nu_A)^3 \tag{18}$$

The most significant advantage of using the CIMAS method to determine the importance of the criteria is that it enables reliability testing. Another feature of the method is that it allows weighting evaluations based on experts' scores. The method's steps are as follows [17]. To facilitate understanding of the proposed Euclidean distance–based CIMAS model integrated with Fermatean fuzzy sets, a conceptual diagram has been added (Figure 1). The figure summarizes the six main stages of the approach: (1) collecting expert information, (2) calculating expert weights using Euclidean distance, (3) transforming linguistic evaluations into Fermatean fuzzy numbers, (4) aggregating and normalizing decision matrices, (5) defuzzifying and determining criteria differences, and (6) computing normalized criteria weights and reliability indices. Overall, Equations (19)–(27) sequentially transform subjective expert inputs into objective, reliability-tested weights. Each computational step progressively enhances the model's accuracy by reducing bias and validating consistency. The input decision-making matrix is defined as Equation (19).

$$D = \left[d_{ij}\right]_{e\times n} \tag{19}$$

where d is the Fermatean fuzzy number for n criteria of e experts. Next, the weighted matrix is obtained by Equation (20).

$$y_{ij} = d_{ij}E_i \tag{20}$$

Afterwards, the weighted matrix's values are defuzzified via Equation (21).

$$c_{ij} = score\left(y_{ij}\right) \tag{21}$$

Then, the normalized matrix's values are calculated with the help of Equation (22).

$$f_{ij} = \frac{c_{ij}}{\sum_{i=1}^{e} c_{ij}} \tag{22}$$

After that, the maximum value of each criterion is selected using Equation (23), and the minimum value of each criterion is determined using Equation (24). Then, the difference between these values of each criterion is calculated by Equation (25) [18].

$$max_j = \max_i f_{ij} \quad (23)$$

$$min_j = \min_i f_{ij} \quad (24)$$

$$diff_j = max_j - min_j \quad (25)$$

The weights of criteria are defined by normalizing the difference values with the help of Equation (26).

$$w_j = \frac{diff_j}{\sum_{j=1}^{n} diff_j} \quad (26)$$

Finally, the reliability index is computed for the reliability test. For this, the second evaluations are collected using a score of 0 to 100 for each criterion by experts. Next, scores for each criterion are averaged. Then, Equation (27) is estimated.

$$RI = \frac{\sum_{j=1}^{n} |100 w_j - s_j|}{100} \quad (27)$$

Where s refers to the average score. The fermatean fuzzy numbers are used for all processes [19].

4. Analysis results

4.1 Results of panel data regression

In this study, three public and three private participation banks that were active during the period from 2021 to 2023, when the exchange rate-protected deposit practice was implemented in Turkey, were considered. Quarterly data, which is the most common, harmonized, and accessible form of data for the period in question, are used by drawing from the CBRT, the PBAT, the BIST, TurkStat, and the data banks of the participating banks. Since exchange rate-protected deposits have been in place for only a short time and are still ongoing, it may be necessary to wait for more data to support a more effective analysis. However, the available data is substantial for an analysis in this scope. The findings and recommendations to be put forward within the scope of this analysis will be binding on the participating banks that constitute the study's sample. The model developed through this study can be adapted for other banking sectors and more general firms in the future.

Return on assets (ROA) is one of the leading indicators of enterprise profitability. Return on assets is calculated as profit divided by total assets. It shows the extent to which enterprises use their assets rationally and the extent to which they make a profit in return for the value of the assets they use. Another profitability indicator is return on equity (ROE), which is calculated as profit divided by equity. Return on equity is important for showing the extent to which the owners or shareholders of an enterprise earn a profit in return for the capital they invest. Independent variables are divided into two groups. The first macro-level variable in the first group is CHD, the main subject of the study. The CHD refers to the amount of TL deposits in banks as per the practice that started at the end of 2021 in Turkey. Based on the 1st-quarter 2021 data, the change values in other periods (CHDΔ) are used as the main independent variable in the study. This variable is calculated by dividing the difference between two different periods by the previous period. Other macro variables are the change value of GNP (GNPΔ), the logarithm values of CPI (lnCPI), the logarithm values of industrial production index (lnIPI), the change value of exchange rate (CURΔ), and interest rate (INT) based on Q1 2021 data. The second group of independent variables consists of micro-level variables within the firm. The second group of independent variables consists of the logarithm values of banks' total assets (lnGR), total loans/total assets values (TLTA) indicating the proportion of assets provided by loans, total equity/total assets values (ETA) indicating the proportion of assets provided by equity, personnel expenses/total expenses values (PETE) indicating the share of personnel expenses in total expenses and off-balance sheet activities/total assets values (OBATA) comparing off-balance sheet activities and total assets.

The research's analysis outputs have been organized into combined tables, where all relevant panel data models and tests are presented together, although in separate tables for the two independent variables for easier use and evaluation. Thus, all possible models can be easily compared, and the tests can be used to determine which model is more appropriate. For this purpose, in addition to the three main models of pooled least squares, fixed effects, and random effects methods, robust models are also included. Thus, the analysis results and tests for five models are summarized in Table 1.

Table 1 presents the pooled least-squares, fixed-effects, random-effects, robust fixed-effects, and robust random-effects models for return on assets, along with their tests. In this framework, the Arellano robust test is considered. The inclusion of pooled, fixed, random, and robust models aims to assess the robustness of the empirical results across different assumptions about unobserved heterogeneity and error variance. Therefore, the fixed effects estimator was chosen as it provides consistent results by controlling for these unobservable bank-specific attributes. The use of robust models further ensures that the estimates remain stable against heteroskedasticity or serial correlation. All models produced significant results. The F statistic value (7.98, 7.76, 5.68, respectively), which tests for the presence of unit effect, is greater than the table value, and the null hypothesis of no unit effect is rejected, indicating the presence of unit effect. Thus, despite the pooled model, alternative models that allow for a unit effect are presented for consideration.

Secondly, the Hausman test was applied to investigate the efficiency of fixed- and random-effects models; the test statistic was 9.84, and the p-value was 0.00. Hence, it is concluded that this analysis is statistically significant. Therefore, the H0 hypothesis is rejected. Upon rejecting the H0 hypothesis, it is concluded that the fixed effects estimator is consistent. To assess the suitability of the panel data estimators and to justify the use of robust standard errors, a set of diagnostic tests is conducted. First, serial correlation in the idiosyncratic errors is examined by the Wooldridge test for autocorrelation in panel data. The results indicate the presence of first-order serial correlation ($p<.05$), suggesting that the standard fixed-effects estimators may produce inefficient and biased standard errors. Moreover, heteroskedasticity is analyzed using the Breusch–Pagan test. The BP statistics are confirmed to have heteroskedasticity across panels ($p<.05$). These findings provide strong justification for adopting robust standard errors in all estimated models. Potential endogeneity can arise due to reverse causality and omitted-variable bias.

Table 1. Panel data analysis results of models for return on assets (ROA)

Variable	Pooled		Fixed Effects		Random Effects		Robust Fixed Effects		Robust Random Effects	
	Coef.	t	Coef.	t	Coef.	z	Coef.	T	Coef.	Z
CHDΔ	0.001*	2.44	0.001*	1.69	0.001*	2.44	0.001*	1.9	0.001**	2.62
TLTA	-0.041*	-2.57	-0.011*	-0.53	-0.041*	-2.57	-0.0078	-0.34	-0.041*	-2.43
ETA	0.060	1.69	0.279**	2.71	0.060	1.69	0.249	1.95	0.060	1.58
PETE	-0.012	-0.79	0.015	0.56	-0.012	-0.79	0.015	0.53	-0.010	-0.58
OBATA	0.001*	2.4	0.001*	0.13	0.001*	2.4	0.000	0.24	0.001*	2.21
GNPΔ	-0.001	-0.6	-0.001	-0.69	-0.001	-0.6	-0.001	0.02	-0.001	-0.58
lnCPI	-0.019	-2.37	-0.022*	-2.59	-0.019*	-2.37	-.0223*	-2.32	-0.021*	-2.52
INT	-0.001	-0.93	0.001	0.21	-0.001	-0.93	0.001	0.02	-0.001	-0.81
lnGR	0.000	-0.22	0.010	1.97	0.000	-0.22	0.008	1.39	0.000	-0.23
lnIPI	0.054***	4.47	0.069***	5.44	0.054***	4.47	0.072***	5.13	0.055***	4.66
CURΔ	-0.016	-0.69	-0.017	-0.76	-0.016	-0.69	-0.005	-0.18	-0.014	-0.59
_cons	-0.118	-1.63	-0.389**	-3.38	-0.118	-1.63	-0.322*	-2.69	-0.118	-1.62
r2_w			0.635		0.574		0.585		0.576	
sigma_u			0.007		0		0.006		0	
sigma_e			0.005		0.005		0.005		0.005	
Rho			0.686		0					
F	7.98***		7.76***				5.52***			
LR			63,69***							
Wald chi2					87.7***				80.6***	
e(lm)					0					
Hausman			9.84*							
DB			2.15							
LBI			2.31							

To address these concerns, additional models are established with lagged independent variables as robustness checks. In addition, the variables are lagged by one period, as this lag length is commonly used in panel-data settings to mitigate simultaneity without excessively reducing sample size. Alternative lag structures are also tested, but these do not materially change the results. The analysis shows that the increase in TL deposits resulting from the CHD practice has a positive impact on the financial performance of participating banks. Undoubtedly, this situation can be considered a success in terms of financial performance and profitability of participation banks. Here, by guaranteeing a margin equal to the increase in the exchange rate instead of the decrease in interest rates, the participation shares to be paid by the banks was reduced and transferred to the responsibility of the treasury initially and then to the CBRT. Thus, as the analysis indicates, the profitability of participating banks increased significantly during the implementation period.

4.2 Results of fuzzy decision-making model

In the fuzzy evaluation phase, ten experts were selected using purposive sampling to ensure both academic and practical representation. The panel included five senior executives from participation banks, three academics specializing in Islamic finance and risk management, and two policy experts from regulatory institutions. The main selection criteria were a minimum of 15 years of professional experience, direct involvement in participation banking operations or regulation, and recognized expertise demonstrated by certifications or publications in related fields.

Based on the experts' importance priorities, the matrix is constructed using age, total years of experience, industry experience, manager experience, and the number of patents or certificates held by the experts. Then, the arithmetic means and standard deviations of the columns are computed to obtain z-score values. It is identified that the average age of experts is 51.2. Moreover, the minimum total experience is 20 years. Similarly, the minimum manager experience of the ten experts is 9.7 years. Next, using these statistical values, a standardized matrix is obtained. Afterwards, the negative values are determined. Euclidean distances between experts and negative values are calculated. Finally, the experts' scores are defined by normalizing the distances. The details of the experts' scores are shown in Figure 1.

Figure 1 shows that the most important evaluation is Expert-6 with 0.210. This expert has the maximum age, total experience years, industry experience years, and manager experience years. Expert-6 received the highest total weight in the Fermatean fuzzy expert-weighting process. It is crucial to remember that this outcome does not suggest priority based only on age or years of experience. Instead, following standardization, a number of factors are combined to establish the final weight. Although the standardization procedure guarantees comparability across several scales, it can potentially magnify relative disparities for specific features. Because of this, even though the weighting algorithm considers all factors simultaneously, age and experience seem to have a greater impact.

The empirical result and our conceptual argument that assigning weights solely on the basis of experience would be impractical are reconciled by this explanation. The criteria set is financial performance (FNPRF), risk management (RSKMNG), interest-free finance compliance (INFNNCMP), macroeconomic impact (MCRIMP), and policy impact (PLCIMP) for the evaluation process. Ten experts evaluate the importance of these criteria. These linguistic evaluations are converted to Fermatean fuzzy numbers. Thus, the input decision-making matrix is defined. Next, the weighted matrix is obtained.

The E values are used as weight values. Afterwards, the weighted matrix's values are defuzzified. Then, the normalized matrix's values are calculated. After that, the maximum value of each criterion is selected, and the minimum value of each criterion is determined. Then, the difference between these values of each criterion is calculated. The weights of the criteria are defined by normalizing the difference values. Finally, the reliability index is computed for the reliability test. For this, the second evaluations are collected using a score of 0 to 100 for each criterion by experts. Next, scores for each criterion are averaged. The details of the weighting results are given in Table 2.

Table 2 identifies that RI is .085. In other words, this value is smaller than 0.1 [20]. Thus, the result is reliable. In this case, the most important criterion is interest-free finance compliance with .294. The second important criterion is risk management with .223. In addition, sensitivity analysis is performed. For this, scenarios are constructed with minimal changes to each expert's score value.

That is, for the first scenario, the score of the first expert is increased by 10% and CIMAS is applied by normalizing the score values. This tests the robustness of the results against expert input. The results are shared in Table 3. As shown in Table 3, the criteria's priorities are the same across scenarios. This demonstrates how robust the results are to expert input. As the research reveals, compliance with interest-free finance principles and effective risk management are the two primary factors determining the integration of currency-hedged deposit products into the systems of participation banks in Turkey.

Participation banking, by its very nature, rejects interest-based transactions and prioritizes asset-based, real-economy financial activities. Therefore, the use of products such as foreign exchange-hedged deposits within the framework of participation finance is only possible if they are designed in full compliance with the principles of interest-free finance. The inclusion of interest-like return mechanisms or speculative currency risk within the product poses a serious risk of non-compliance for participation banking. Therefore, compliance with interest-free terms is a prerequisite for the ethical and legal acceptance of these products.

Risk management for participation banks is much more complex than for conventional banks, as interest-free finance principles are based on risk sharing but reject speculative risk-taking (gharar). Factors such as exchange rate volatility, market risk, and liquidity risk are inherently high in foreign exchange-protected deposit products. Therefore, it becomes critical for participating banks to integrate both Sharia-compliant risk management tools and modern financial protection mechanisms.

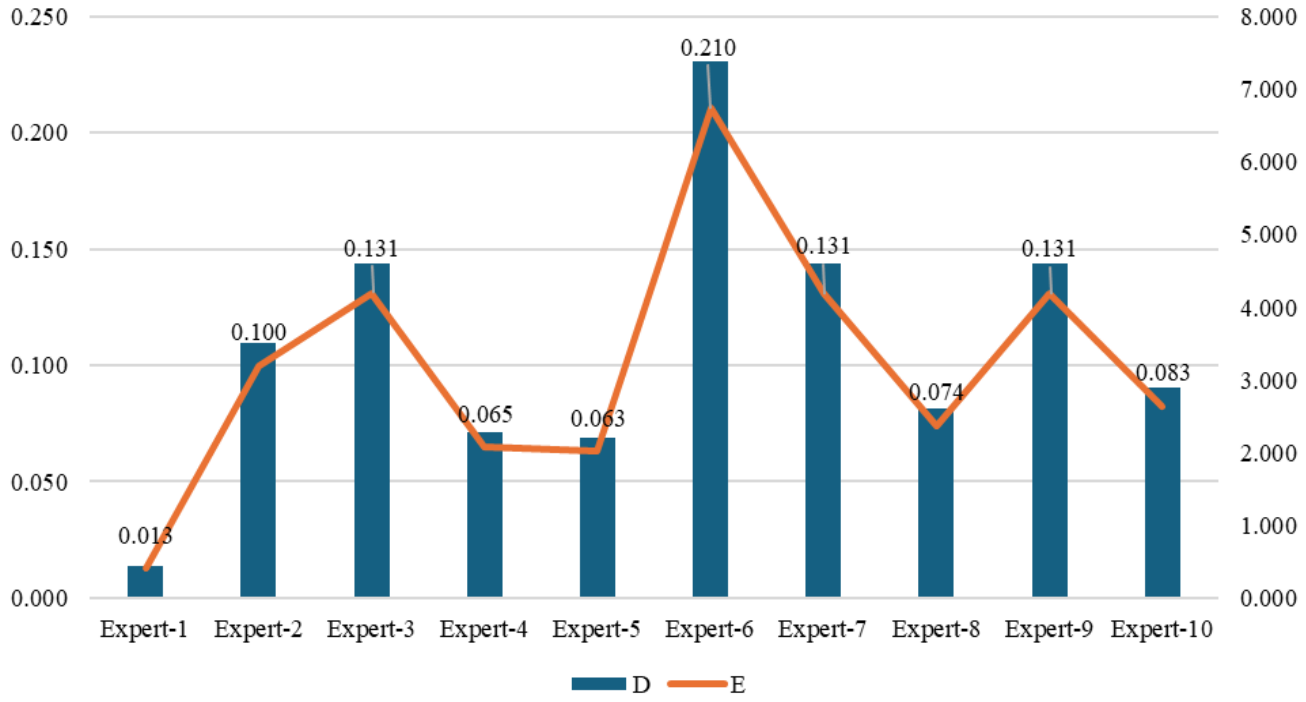

Figure 1. Scores of the experts

Table 2. Significance weights of the criteria

	FNPRF	RSKMNG	INFNNCMP	MCRIMP	PLCIMP
Maximum	.250	.306	.386	.199	.203
Minimum	.020	.019	.009	.007	.005
Difference	.230	.286	.377	.192	.198
Weight	.179	.223	.294	.150	.154
Second	17	21.2	27.9	14.2	19.7
RI	.085				

Table 3. Sensitivity analysis results

	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7	SC-8	SC-9	SC-10	SIWEC
FNPRF	3	3	3	3	3	3	3	3	3	3	3
RSKMNG	2	2	2	2	2	2	2	2	2	2	2
INFNNCMP	1	1	1	1	1	1	1	1	1	1	1
MCRIMP	5	5	5	5	5	5	5	5	5	5	5
PLCIMP	4	4	4	4	4	4	4	4	4	4	4

5. Conclusion

This study aimed to examine the financial and ethical implications of the Currency-Hedged Deposit (CHD) system for participating banks in Turkey, employing an integrated analytical framework combining econometric modeling and fuzzy decision-making techniques. The motivation for this research stemmed from the growing need to assess how macro-level stabilization policies, such as the CHD mechanism, influence financial performance, risk exposure, and compliance with interest-free principles of participation banks. In the first stage of the analysis, a panel data regression is conducted using quarterly data from six participating banks from 2021 to 2023. The findings demonstrated that the CHD variable has a positive, statistically significant effect on the profitability indicators—particularly return on assets (ROA)—of participating banks. This suggests that the CHD mechanism contributed to short-term improvements in profitability and liquidity stability by mitigating currency risk and transferring part of the risk burden to public financial institutions. However, the study also emphasizes that the sustainability of such improvements depends on maintaining compliance with Islamic financial ethics and effective long-term risk management strategies. In the second stage, the study introduced a hybrid decision-making approach using a Euclidean distance-based CIMAS model with Fermatean fuzzy sets to incorporate expert judgments. The fuzzy analysis revealed that interest-free finance compliance and risk management are the most critical criteria for the ethical legitimacy and systemic sustainability of participation banks under the CHD framework. Sensitivity analysis confirmed the robustness and internal consistency of these results, highlighting that adherence to Sharia principles and effective risk governance must coexist to ensure sustainable innovation in Islamic finance. This study contributes to the literature in several ways. First, it integrates quantitative econometric evidence with fuzzy logic-based decision modeling, providing a multidimensional understanding of financial innovation in Islamic banking. Second, it introduces a novel methodological framework that bridges the empirical rigor of econometrics with the flexibility and uncertainty-handling capabilities of fuzzy systems.

Third, it offers valuable insights for regulators and policymakers aiming to balance financial innovation, ethical compliance, and systemic stability in developing countries. The two stages of the analysis are conceptually and empirically interconnected. The econometric results obtained in the first stage provided a quantitative foundation for the fuzzy evaluation by identifying which financial and macroeconomic variables—such as CHD growth, equity ratios, and personnel expenses—significantly affect profitability. These statistically significant factors were then translated into expert-assessed criteria within the fuzzy model, in which experts evaluated their relative importance for ethical compliance, risk management, and macroeconomic relevance. Conversely, the fuzzy stage contextualized and validated the econometric outcomes by highlighting that profitability gains from CHD are sustainable only when supported by sound governance and compliance with the principles of interest-free finance. In this way, the fuzzy decision-making model not only complements but also interprets the econometric findings, creating a feedback loop that enhances both the analytical rigor and the practical implications of the study. Nevertheless, this research is subject to certain limitations. The dataset covers a relatively short time period (2021–2023), given the recent introduction of the CHD system, which may restrict the generalizability of long-term effects. Moreover, the fuzzy decision-making model relies on expert-based judgments, which, while statistically validated, may contain subjective biases. Future research could extend this work by adopting longer time horizons, incorporating additional macroeconomic variables, and conducting cross-country comparisons to understand how similar mechanisms operate across different Islamic banking ecosystems. Furthermore, integrating machine learning algorithms with fuzzy inference systems could enhance predictive accuracy and enable dynamic decision-support models for policy analysis. In conclusion, the study underscores that while the CHD system can temporarily strengthen the financial performance of participating banks, its sustainable success requires a careful balance between economic efficiency, ethical compliance, and robust risk management—an equilibrium that hybrid analytical frameworks such as the one proposed here are particularly well-suited to evaluate.

Ethical issue
The authors are aware of and comply with best practices in publication ethics, specifically regarding authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with research ethics policies. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement
The manuscript contains all the data. However, more data will be available upon request from the authors.

Conflict of interest
The authors declare no potential conflict of interest.

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