



Ranking Sovereign Sukuk Issuance Outcomes Under Macroeconomic Regime Shifts: A Picture Fuzzy Multi Criteria Framework for Turkish Treasury Auctions

Cihan Ozbek^{1,*}

1 Vakıf Katılım Bankası A.Ş., Istanbul, Turkiye

ARTICLE INFO

Article history:

Received 10 July 2026

Received in revised form 9 September 2026

Accepted 18 October 2026

Available online 27 October 2026

Keywords:

Picture fuzzy sets; Entropy; TOPSIS; VIKOR; Sovereign debt

ABSTRACT

Sovereign sukuk auctions represent a structural funding channel for the Turkish Treasury, but their outcomes have not been systematically evaluated as multidimensional design decisions under different macroeconomic regimes. This study assembles all 66 domestic lease certificate auctions held between November 2018 and December 2025 and evaluates 53 fixed-rate auctions using four regime-adjusted criteria: the coupon relative to the prevailing central bank policy rate, maturity, the auction share in the monthly Treasury borrowing program, and the coupon spread over a maturity-matched conventional Treasury benchmark. Entropy weights are cross-checked using Criteria Importance Through Intercriteria Correlation (CRITIC), the Method Based on the Removal Effects of Criteria (MEREC), and logarithmic percentage change-driven objective weighting. Picture fuzzy ratings are calibrated from auction outcomes, with hesitation linked to bootstrap estimation uncertainty rather than an arbitrary formula. Picture fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Multi-Criteria Optimization and Compromise Solution (VIKOR), using picture fuzzy weighted aggregation, produce independent rankings. Weighted Aggregated Sum Product Assessment (WASPAS), Combined Compromise Solution (CoCoSo), and Measurement of Alternatives and Ranking According to Compromise Solution (MARCOS) provide additional cross-checks. The five ranking methods demonstrate strong agreement: the Kendall coefficient between the picture fuzzy methods is 0.8084, and pairwise Spearman correlations are at least 0.915. The leading designs are direct-sale placements between 2019 and early 2021 that accounted for the entire monthly auction funding program, led by the December 2020 five-year placement and the low-cost February and August 2019 placements. Rankings remain stable under five alternative weighting schemes, halved and doubled uncertainty scales, the removal of 2020 and all auctions with missing benchmark cells, compromise-parameter sweeps, and rank-reversal tests involving 1,000 bootstrap resamples. The findings are consistent with preferred-habitat and clientele interpretations of the participation-bank investor base and provide insights into auction design under disinflation. From a policy perspective, the proposed framework can support Treasury decision-makers in identifying auction structures that balance funding costs, maturity considerations, and borrowing-program requirements under changing monetary conditions.

* Corresponding author.

E-mail address: cihanozbek34@gmail.com

1. Introduction

Sovereign sukuk have become a standard component of government funding in Türkiye. The Treasury has placed lease certificates in the domestic market since 2012 through a special purpose vehicle that leases state assets and distributes the rental income to certificate holders, and the program now supplies a sizable fraction of gross domestic borrowing in Turkish lira, having grown from a single three billion lira auction in 2018 to more than two hundred billion lira across nine auctions in 2025 [1]. Every auction in this program is a design act. The issuer selects a maturity, a size, a coupon structure, and a payment calendar, and the market responds with an accepted volume at a given coupon. Yet the academic literature has treated sovereign sukuk almost exclusively as a pricing object in the secondary market, with spread and co movement studies leading the field [2]. The primary auction sequence, where the design decision actually lives, has not been evaluated as a decision problem.

This paper constructs and executes that evaluation for Türkiye. We treat each domestic fixed rate lease certificate auction executed between November 2018 and August 2025 as an alternative in a multi criteria decision problem and rank the fifty three auctions on four criteria that are purged of inflation illusion. The first criterion measures the auction coupon against the central bank policy rate that prevailed on the auction day, in line with the relative cost logic of tax smoothing public finance [3], so that a seven percent coupon in 2020 is not compared directly with a forty percent coupon in 2024 as if they meant the same thing. The second criterion is maturity, whose valuation in government bond markets reflects habitat and segmentation [4, 5]. The third criterion is the share of the auction in the Treasury borrowing program of its month, which replaces nominal size and answers whether the certificate channel carried the funding plan or merely supplemented it, a role that the institutional record of the Turkish certificate market documents in detail [1]. The fourth criterion is the coupon spread over a maturity matched conventional Treasury benchmark auctioned in the same or an adjacent calendar month, in the spirit of the matched benchmark comparisons of the sukuk spread literature [2, 6].

Three features of the problem motivate a picture fuzzy multi criteria design rather than a regression or an efficiency frontier, following the multi criteria tradition in financial evaluation [7]. The evaluation object is a ranking of discrete design configurations, not the estimation of a causal effect, which rules out regression as the primary instrument. Data envelopment analysis and stochastic frontier analysis require an input output production structure with multiple comparable decision making units, whereas here there is a single issuer whose auctions differ in design, so an efficiency frontier is conceptually misplaced. What remains is a set of auction outcomes measured on heterogeneous criteria that mix cost and benefit directions and that carry estimation uncertainty of different magnitudes, which is exactly the situation for which picture fuzzy multi criteria methods were developed [8, 9].

The design choices in this paper respond to three weaknesses that recent methodological debates have attached to fuzzy multi criteria studies in finance. Dependence on expert scoring is the most visible weakness. Every rating in this study is calibrated from a published auction outcome, and the hesitation grade of each picture fuzzy number is set equal to the bootstrap estimation uncertainty of the underlying normalized value, so no ad hoc hesitation parameter and no subjective expert panel enters the model. A further weakness is the use of crisp score shortcuts inside fuzzy methods. The VIKOR stage aggregates regrets with the picture fuzzy weighted averaging operator and defuzzifies only at the compromise index, so the fuzzy structure survives until the last step. Single method reporting completes the list of weaknesses. Rankings are produced by two picture fuzzy methods and by three modern cross checks from the weighted sum product and utility ratio families, and every substantive claim is tested against five objective weighting schemes and a battery of resampling and removal exercises.

The contributions are three. Empirically, the paper delivers a complete regime adjusted ranking of sovereign sukuk auctions and shows that the strongest funding outcomes were achieved before the tightening cycle, when coupons cleared several points below the policy rate and the certificate channel carried most of the monthly borrowing program. Methodologically, it couples data calibrated picture fuzzy ratings with estimation uncertainty based hesitation and a genuinely fuzzy VIKOR stage, a combination that has not been applied to sovereign debt design. For practice, it provides debt managers with a transparent audit instrument in which every new auction can be inserted in real time and its standing in the program read off immediately.

The remainder of the paper proceeds as follows. Section 2 develops the theoretical framework. Section 3 reviews the literature critically. Section 4 presents the methodology. Section 5 describes the data and the criteria. Section 6 reports the results. Section 7 presents robustness and additional tests. Section 8 discusses the findings against the literature and states the limitations. Section 9 concludes.

However, the sovereign primary auction sequence has not yet been evaluated as a regime-adjusted, multi-criteria design problem, and existing fuzzy multi-criteria applications commonly rely on expert-assigned ratings or crisp aggregation. This gap is important because nominal coupons and auction sizes are not directly comparable across Türkiye's inflation regimes, while maturity, relative cost, and the program share represent distinct dimensions of issuance design. Accordingly, this study ranks the fixed-rate domestic sovereign sukuk auctions using outcome-calibrated picture fuzzy ratings with uncertainty-based hesitation and examines whether the resulting ordering remains stable across alternative weighting and decision-making methods.

2. Theoretical Framework

The supply side of the framework rests on two theories. Preferred habitat theory and the market segmentation hypothesis hold that borrowers face distinct maturity segments with imperfect arbitrage between them, so the maturity of an auction is a strategic variable rather than a detail [4, 5]. An issuer that places a long dated instrument at an acceptable spread lengthens the effective maturity of the debt stock and reduces rollover risk, which is why maturity enters the evaluation as a benefit. Granular evidence on public debt maturity structure confirms that maturity composition carries policy content in emerging markets [10]. The tax smoothing and fiscal insurance view of public debt holds that the state should borrow at the lowest available relative cost across instruments while keeping the debt service profile stable, which formalizes the role of the policy rate spread criterion [3].

The demand side rests on three further theories. The clientele effect holds that distinct investor groups attach to distinct instrument characteristics, and the dominant buyers of Turkish lease certificates are participation banks whose balance sheets require interest free assets for liquidity and ratio compliance. Banking regulation in Türkiye treats lease certificates as eligible assets for the liquidity coverage and liquidity ratio calculations of participation banks, which turns the certificate market into a preferred habitat for a captive investor base that conventional Treasury paper cannot reach [1]. The design of central bank liquidity instruments for Islamic banking systems shows that this habitat is a general feature of interest free finance rather than a Turkish idiosyncrasy [11]. This clientele is the structural reason why the relative cost criterion, rather than the absolute coupon, carries the pricing signal of the design. Auction theory and the winner's curse literature show that auction format and information structure move the division of surplus between issuer and bidders [12, 13], and signaling theory implies that the terms an issuer accepts in the primary market reveal its private information about funding conditions [14]. The two cost criteria in the model, the policy rate spread and the benchmark spread, are the empirical signatures of this auction and signaling channel.

The framework yields a direct prediction that the results section tests. If the participation bank clientele is a genuine preferred habitat with limited arbitrage against the conventional curve, certificate auctions should at times fund below both the policy anchor and the matched conventional benchmark, and the size of that advantage should vary with regime rather than disappear under deflation of the data.

3. Literature Review

The sukuk pricing literature converges on the view that sukuk and conventional bonds share macro drivers yet trade in partially segmented markets. Spread studies document that macroeconomic announcements move sukuk with signs that partly mirror conventional markets and that common components coexist with idiosyncratic residuals [2, 15]. Primary and secondary spreads respond jointly to issuer characteristics and tenor structure [16]. The wedge between the two instruments in Malaysia reflects liquidity and tax treatment rather than credit [6], and recent work reads the same wedge through an environmental, social, and governance lens [17].

The macro development record points the same direction. Sovereign sukuk growth responds to macroeconomic conditions [18], and sustainability oriented issuance is reshaping the supply side of the market [19, 20]. Read together, these studies deliver two lessons for the present design. The pricing object in almost all of them is the secondary market spread or the corporate primary spread, and the sovereign primary auction, where the state itself chooses terms, remains unexamined as a sequence of design decisions. The persistence of segmentation documented in this stream predicts the relative cost advantages that the criteria of this paper measure. The Turkish primary market, where placements run through direct sales to a bank dominated clientele, is the cleanest available laboratory for that prediction because clientele segmentation is visible in the auction data themselves.

The fuzzy multi criteria stream supplies the machinery, and its use in finance has broadened well beyond the early firm ranking exercises [7]. The methodological core has moved toward richer set structures that carry an explicit neutral grade, from intuitionistic to spherical and picture fuzzy sets [8, 9, 21], and a decade of applications has consolidated the picture fuzzy position in multi criteria decision making [22]. Entropy pairing with TOPSIS has become a reproducible standard in this line [23]. The ranking families divide the labor by construction principle, with additive multiplicative compromise in WASPAS and CoCoSo and utility ratios against ideal references in MARCOS [24–26]. Recent financial applications extend the same families to FinTech performance evaluation [27], bank and firm performance analysis [28], and portfolio choice in volatile markets [29]. On the weighting side, MEREC derives weights from removal effects [30] and LOPCOW from logarithmic percentage changes [31], while hybrid entropy constructions continue to refine objective assignment [32]. Studies of criteria removal further show that rankings deserve explicit stability audits before they inform decisions [33].

These methods are chosen as complements rather than substitutes. TOPSIS rests on Euclidean distance to an ideal, VIKOR on maximal regret, WASPAS and CoCoSo on additive and multiplicative compromise constructions, and MARCOS on utility ratios against an ideal and an anti ideal reference, so the battery spans the four dominant aggregation philosophies of the modern literature, while MEREC and LOPCOW correct the sensitivity of entropy to outlier dispersion through their logarithmic structures. Two gaps in this stream motivate the methodological choices that follow. The ratings in nearly all applications come from expert panels, which exposes results to elicitation bias and blocks replication. And fuzzy VIKOR implementations frequently collapse to a crisp score matrix before the aggregation stage. This study addresses the first gap with outcome calibrated ratings whose hesitation equals estimation uncertainty, and the second with a picture fuzzy weighted aggregation that stays fuzzy until the compromise index.

4. Methodology

4.1. Picture Fuzzy Preliminaries

A picture fuzzy set A on a universe X assigns to each element three grades, positive membership $\mu_A(x)$, neutral membership $\eta_A(x)$, and negative membership $\nu_A(x)$, with $\mu_A(x) + \eta_A(x) + \nu_A(x) \leq 1$ [8]. The refusal grade $\pi_A(x) = 1 - \mu_A(x) - \eta_A(x) - \nu_A(x)$ completes the unit interval. A picture fuzzy number is written $a = (\mu_a, \eta_a, \nu_a, \pi_a)$. The Euclidean distance between two picture fuzzy numbers a and b used throughout is

$$d(a, b) = \sqrt{1/2 [(\mu_a - \mu_b)^2 + (\eta_a - \eta_b)^2 + (\nu_a - \nu_b)^2 + (\pi_a - \pi_b)^2]} \quad (1)$$

The score $s(a) = \mu_a - \nu_a$ ranks numbers, and the accuracy $h(a) = \mu_a + \eta_a + \nu_a$ breaks ties. When $\eta_a = 0$ for all a the structure reduces to an intuitionistic fuzzy set, and the calibration below retains a nonzero neutral grade.

4.2. Outcome Calibration with Estimation Uncertainty

Let $r_{ij} \in [0, 1]$ be the min max normalized performance of auction i on criterion j , oriented so that larger is better. The estimation uncertainty of each cell is measured by a bounds perturbation bootstrap. The auction set is resampled B times with replacement, the normalization bounds of each criterion are recomputed inside every resample, and the standard deviation σ_{ij} of the normalized value of auction i on criterion j across these perturbed bounds measures how sharply that auction is located on the criterion scale. The picture fuzzy rating of auction i on criterion j is

$$\pi_{ij} = 0.5 \frac{\sigma_{ij}}{\max_{i,j} \sigma_{ij}}, \quad \eta_{ij} = 0.2 (1 - \pi_{ij}) 4 r_{ij} (1 - r_{ij}) \quad (2)$$

$$\mu_{ij} = (1 - \pi_{ij} - \eta_{ij}) r_{ij}, \quad \nu_{ij} = 1 - \mu_{ij} - \eta_{ij} - \pi_{ij} \quad (3)$$

The refusal grade π_{ij} equals the estimation uncertainty of the normalized value, computed by perturbing the normalization bounds over bootstrap resamples and scaled so that the least precisely measured cell carries a refusal grade of one half. The neutral grade peaks at the middle of the performance scale, where a debt manager is plausibly indifferent, and vanishes at the extremes. Membership and non membership split the remaining mass in proportion to performance, with the normalized performance clamped inside the open unit interval so that no cell becomes an absorbing element of the weighted aggregation. Every grade is therefore a deterministic function of published data and of a resampling seed, and no subjective input enters the matrix.

4.3. Objective Weighting

Four objective schemes weight the criteria. Entropy weighting sets

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^n r_{ij}}, \quad e_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (4)$$

with zero terms contributing zero by convention, and then

$$w_j = \frac{1 - e_j}{\sum_{j=1}^m (1 - e_j)} \quad (5)$$

CRITIC multiplies the dispersion of each criterion by its conflict with the others [34]. MEREC derives weights from the removal effect of each criterion on a logarithmic aggregate performance [30], and LOPCOW weights criteria by the logarithm of the ratio between the root mean square and the standard deviation of their normalized values [31]. Equal weights and standard deviation weights serve as references.

4.4. Picture Fuzzy TOPSIS

For each criterion the positive ideal is the rating with the highest score and the negative ideal is the rating with the lowest score. The separations of auction i from the two ideals are

$$D_i^+ = \sum_{j=1}^m w_j d(\alpha_{ij}, \alpha_j^+), \quad D_i^- = \sum_{j=1}^m w_j d(\alpha_{ij}, \alpha_j^-) \quad (6)$$

and the closeness coefficient

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (7)$$

orders the auctions descending, with weights renormalized over the criteria that carry data for auction i whenever a cell is missing.

4.5. Picture Fuzzy VIKOR with Fuzzy Aggregation

The regret ratio of auction i on criterion j is $g_{ij} = (f_j^+ - s(\alpha_{ij})) / (f_j^+ - f_j^-)$, where f_j^+ and f_j^- are the best and worst criterion scores. Each regret is cast as a picture fuzzy number $\rho_{ij} = (1 - g_{ij}, 0, g_{ij}, 0)$. The group utility and the individual regret of auction i are picture fuzzy numbers obtained with the picture fuzzy weighted averaging operator

$$S_i = \bigoplus_j w_j \otimes \rho_{ij}, \quad R_i = \rho_{ij^*}, \quad j^* = \operatorname{argmax}_j g_{ij} \quad (8)$$

For numbers $\rho_j = (\mu_j, \eta_j, \nu_j, \pi_j)$ and weights w_j the operator returns

$$\mu = 1 - \prod_{j=1}^m (1 - \mu_j)^{w_j}, \quad \eta = \prod_{j=1}^m (1 - \mu_j)^{w_j} - \prod_{j=1}^m (1 - \mu_j - \eta_j)^{w_j} \quad (9)$$

$$\nu = \prod_{j=1}^m (1 - \mu_j - \eta_j)^{w_j} - \prod_{j=1}^m (1 - \mu_j - \eta_j - \nu_j)^{w_j}, \quad \pi = 1 - \mu - \eta - \nu \quad (10)$$

Because the score of ρ_{ij} equals $1 - 2g_{ij}$, both aggregated scores $s(S_i)$ and $s(R_i)$ are benefit oriented, larger values mean smaller regret. The compromise index therefore takes the oriented form

$$Q_i = v \frac{s^+ - s(S_i)}{s^+ - s^-} + (1 - v) \frac{r^+ - s(R_i)}{r^+ - r^-} \quad (11)$$

with $s^+ = \max_i s(S_i)$, $s^- = \min_i s(S_i)$, and analogously for the regret terms, so that smaller Q_i still identifies the better compromise. The acceptance and stability conditions follow the standard VIKOR rules with $v = 0.5$ as the base case and the sweep reported in Section 7.

4.6. Cross Checks and Consensus

WASPAS, CoCoSo, and MARCOS re rank the auctions on the crisp normalized matrix with entropy weights as modern cross checks, following Zavadskas *et al.*, [24], Yazdani *et al.*, [25], and Stevic *et al.*, [26]. A Borda count across all five orderings yields the consensus ranking. Agreement is measured by Spearman rank correlations on the true rank vectors and by the Kendall coefficient between the two picture fuzzy procedures. One thousand bootstrap resamples produce intervals for the closeness coefficient. Whenever the benchmark cell of an auction is missing, the same available case rule renormalizes the criterion weights over the observed criteria in all five ranking methods, so the treatment of incomplete rows is uniform across the battery. Figure 1 summarizes the pipeline.

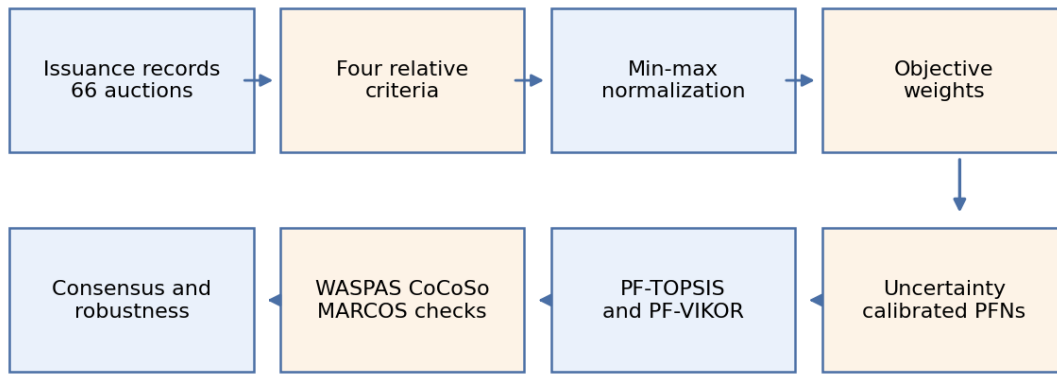


Fig. 1. Methodology pipeline from raw announcements to consensus ranking

5. Data and Criteria

5.1. Institutional Setting and Sample

Domestic sovereign lease certificates in Türkiye are issued by a state-owned asset leasing company that acquires public real estate and leases it back to the Treasury [1]. Rental payments are distributed to certificate holders semiannually. Placements are conducted as direct sales to banks and public institutions through the central bank auction system, and each placement is announced in advance with a term sheet that reports maturity, coupon, and the payment calendar. Money market funds in Türkiye supply the cash management layer through which participation banks adjust their positions around these placements [35]. The sample is the complete population of domestic Turkish lira auctions between November 2018 and December 2025, sixty six auctions in total. Nine auctions carry coupons indexed to consumer prices and four carry coupons indexed to the overnight participation reference rate introduced in late 2025. Because a nominal cost criterion is not comparable across indexation regimes, the main evaluation covers the fifty three fixed rate auctions, and the thirteen indexed auctions are examined separately in Section 7. Appendix Table A1 lists the full population. Figure 2 shows the annual rhythm of the program.

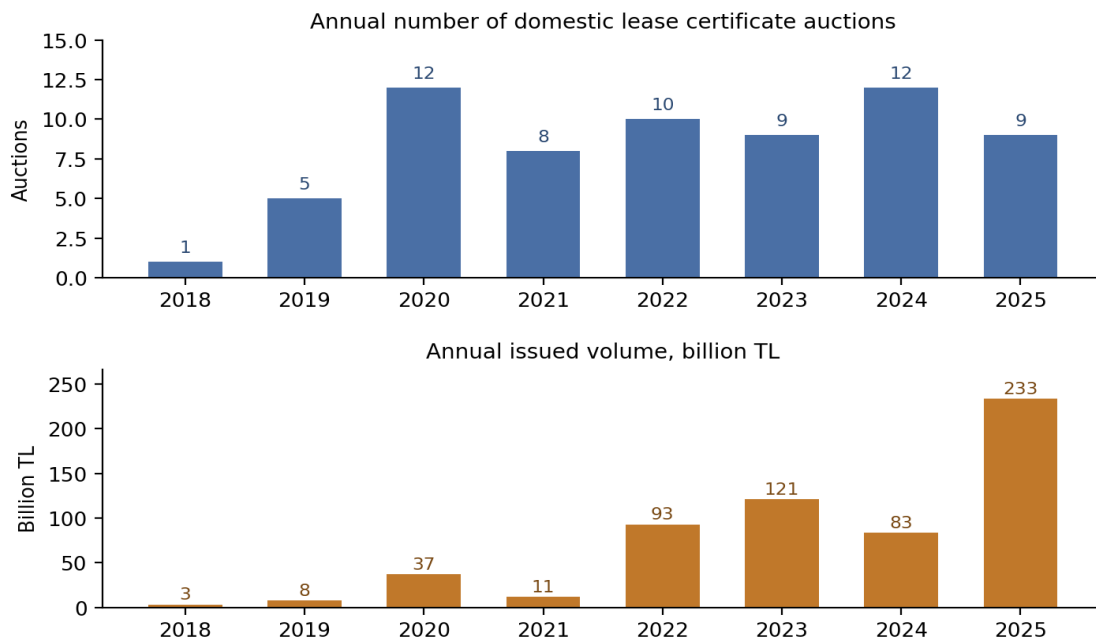


Fig. 2. Annual rhythm of the domestic lease certificate program

5.2. Criteria and Regime Adjustment

Table 1 defines the four criteria and maps each to the theoretical framework of Section 2. The policy rate spread subtracts the central bank policy rate prevailing on the auction day from the annual coupon, so cost

is measured relative to the monetary anchor of its own regime. Because the anchor is an overnight rate, this criterion embeds the slope of the yield curve as well as the instrument wedge, and Section 6.3 separates the two readings. The program share divides the accepted amount of the auction by the total accepted amount of all certificate auctions plus all nominal conventional auctions in the same month, so size is measured against the funding plan of its own month. The ratio is defined for every auction, and it equals one whenever the certificate channel is the only auction-based funding tap of its month. The benchmark spread subtracts the yield of maturity matched conventional auction from the annual coupon in basis points.

Table 1
Evaluation criteria, directions, and theoretical anchors

Criterion	Construction	Direction	Theoretical anchor
Policy rate spread	Annual coupon minus central bank policy rate on the auction day, in percentage points	Cost	Tax smoothing and fiscal insurance
Maturity	Days between settlement and redemption	Benefit	Preferred habitat and market segmentation
Program share	Accepted amount over total certificate and nominal conventional amount of the month, ratio in [0, 1]	Benefit	Clientele effect and regulatory liquidity habitat
Benchmark spread	Annual coupon minus maturity matched conventional auction yield, in basis points	Cost	Auction theory and signaling

Note: Benefit criteria are oriented so that larger values are preferred, and cost criteria so that smaller values are preferred.

The benchmark is built exclusively from primary market instruments priced close in time. For each certificate auction the candidate pool consists of nominal conventional bond and bill auctions placed in the same calendar month with maturity within one hundred twenty days of the certificate maturity. If no candidate exists, the search extends one month backward and forward, and no farther. Realized average annual simple yields are weighted by accepted amounts within the closest month. Ten auctions find no match inside this window and their benchmark cell remains missing. Missing cells are handled by available case normalization, in which each criterion is scaled over its observed values and each auction is scored only on the criteria it carries, with weights renormalized accordingly. Section 7 shows that deleting all ten auctions changes the ranking at a correlation of 1.000.

Table 2 reports descriptive statistics with valid observation counts and the criterion correlation matrix. The largest absolute correlation equals 0.245, so no mechanical redundancy survives the redesign. The policy rate spread averages minus 3.12 percentage points over fifty three auctions and ranges from minus 17.42 to plus 10.30, which documents that certificate coupons cleared below the monetary anchor in most of the sample. The benchmark spread is observed for forty three auctions and averages minus 5.9 basis points. Figure 3 plots coupons against the policy rate and the matched benchmark. Appendix Table A2 lists the prevailing policy rate, coupon, and program share for each auction.

Table 2
Descriptive statistics and pairwise correlation matrix of the evaluation criteria

Panel A. Descriptive statistics										
Criterion	N	Mean	SD	Skew	Kurt	Min	Q1	Median	Q3	Max
Policy rate spread	53	-3.122	6.642	-0.237	0.646	-17.420	-9.100	-1.490	0.910	10.300
Maturity	53	1304.906	917.484	1.436	1.321	182.000	728.000	728.000	1820.000	3640.000
Program share of the month	53	0.306	0.348	1.260	0.012	0.012	0.061	0.149	0.402	1.000
Benchmark spread	43	-5.863	101.397	0.506	5.518	-370.000	-10.000	-1.000	0.000	305.000

Table 2

Continued

Panel B. Pairwise Pearson correlation matrix				
Criterion	Policy rate spread	Maturity	Program share	Benchmark spread
Policy rate spread	1.000	0.182	0.245*	0.204
Maturity	0.182	1.000	-0.219	0.093
Program share	0.245*	-0.219	1.000	-0.126
Benchmark spread	0.204	0.093	-0.126	1.000

Note: N denotes the number of valid auction observations. The benchmark spread is observed for 43 auctions matched within one calendar month and 120 days of maturity. The asterisk denotes two-tailed statistical significance at the ten percent level, and the only significant off-diagonal coefficient is the correlation between the policy rate spread and the program share at 0.245. SD is the sample standard deviation, Skew the skewness, and Kurt the excess kurtosis.

Two features of the descriptive record frame the evaluation. The policy rate spread spans 27.7 percentage points from its minimum to its maximum, which is why regime adjustment is the backbone of the criteria. The program share is right skewed with a median of 0.149, which is why the entropy weighting concentrates on the funding role rather than on the absolute amount.

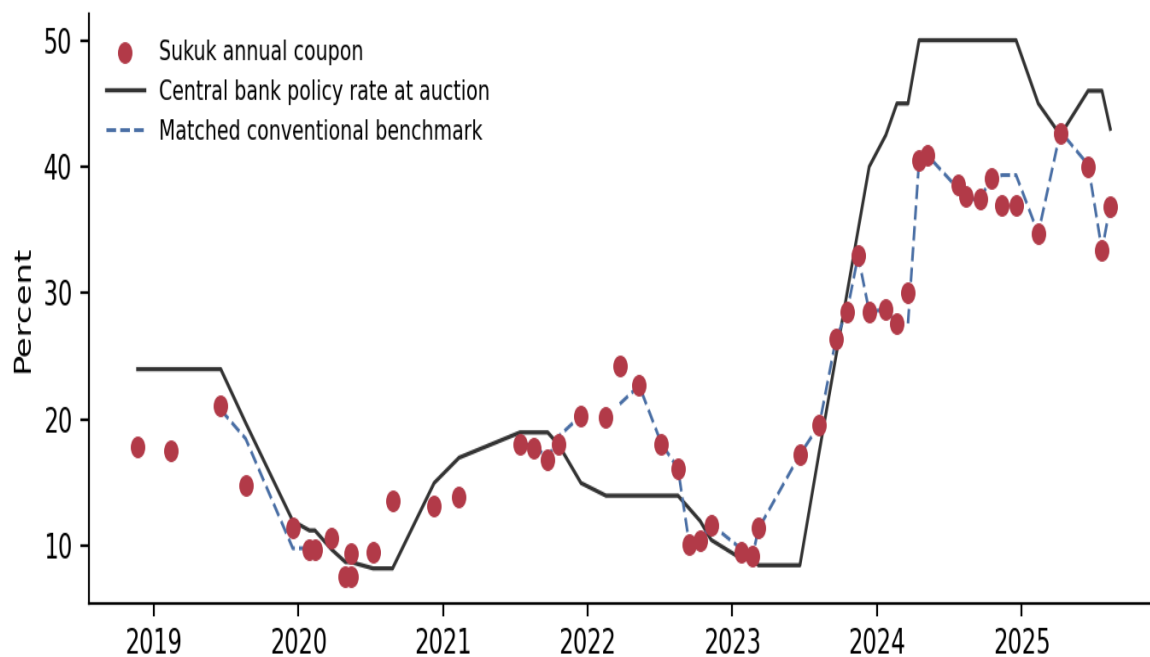


Fig. 3. Sukuk coupons against the policy rate and the matched conventional benchmark

6. Results

Table 3 summarizes the calibrated picture fuzzy grades that feed the rankings. The grades show that the refusal mass concentrates on the benchmark spread criterion, whose mean refusal grade of 0.4269 far exceeds the other criteria, because the ten unmatched auctions carry full refusal grades and the outlier prone distribution of the matched sample, with excess kurtosis of 5.518, makes the normalization bounds the least stable under bootstrap perturbation. The membership and non membership split remains performance driven on every criterion, as the mean score and accuracy columns of Table 3 show.

Table 3

Summary statistics of the calibrated picture fuzzy grades by criterion

Criterion	Mean membership	Mean neutral	Mean non membership	Mean refusal	Mean score	Mean accuracy
Policy rate spread	0.3717	0.1419	0.3989	0.0875	-0.0272	0.9125
Maturity	0.2437	0.1077	0.5307	0.1180	-0.2870	0.8820
Program share	0.2782	0.0693	0.6391	0.0135	-0.3609	0.9865
Benchmark spread	0.2129	0.1052	0.2550	0.4269	-0.0421	0.5731

Note: Entries are sample means across the fifty-three fixed rate auctions, with standard deviations available in the replication files. The benchmark spread row pools all fifty three auctions, and the ten auctions without a matched benchmark carry a full refusal rating, which is why its mean refusal grade is elevated. The score equals membership minus non membership and the accuracy equals membership plus neutral plus non membership, so both follow arithmetically from the reported means. Grades follow Eq. (2) and Eq. (3) and sum to one for every auction criterion cell.

6.1. Weights

Entropy weighting assigns 0.123 to the policy rate spread, 0.265 to maturity, 0.552 to the program share, and 0.060 to the benchmark spread. The program share dominates because it discriminates most evenly across auctions, while the benchmark spread clusters tightly around zero once regime effects are removed and therefore adds the least independent information. CRITIC, MEREC, and LOPCOW distribute weight far more evenly. Table 4 reports the baseline entropy scheme together with five alternative schemes, including the standard deviation and equal weight references, and Figure 4 visualizes the four information based objective schemes.

Table 4

Entropy intermediate parameters and objective criterion weights across six weighting schemes

Criterion	Entropy value (e)	Diversification (d = 1 - e)	Entropy weight (w)	CRITIC	MEREC	LOPCOW	StdDev	Equal
Policy rate spread	0.9665	0.0335	0.1230	0.2126	0.2197	0.2552	0.2413	0.2500
Maturity	0.9277	0.0723	0.2652	0.2635	0.1798	0.2384	0.2672	0.2500
Program share	0.8498	0.1502	0.5515	0.2732	0.2543	0.2294	0.3545	0.2500
Benchmark spread	0.9874	0.0126	0.0603	0.2506	0.3463	0.2771	0.1369	0.2500

Note: The entropy value is the Shannon entropy of the normalized criterion column, and diversification is one minus the entropy value, before weights are normalized to sum to one within each scheme. Entropy is the baseline scheme and the other five are alternatives examined in Section 7. StdDev weights are computed on the normalized decision matrix.

Two patterns in the weights frame the rest of the paper. The entropy scheme concentrates on the program share because that criterion discriminates most evenly across auctions, while the conflict based and logarithmic schemes shift weight toward the cost criteria. Section 7 shows that the ranking survives under all six schemes.

6.2. Rankings of the Auctions

Table 5 summarizes the top ten and bottom five issuance designs, while Table A3 in the appendix reports the complete evaluation of all fifty three auctions. The picture fuzzy TOPSIS ranking places the December 2020 five year auction first with a closeness coefficient of 0.8040. This auction cleared 1.8 percentage points below the policy rate of its day and carried the entire monthly program, because the Treasury ran no nominal conventional auction in that month. The next positions belong to the August 2020, August 2019, and February 2019 auctions, and the February 2021 auction completes the leading group.

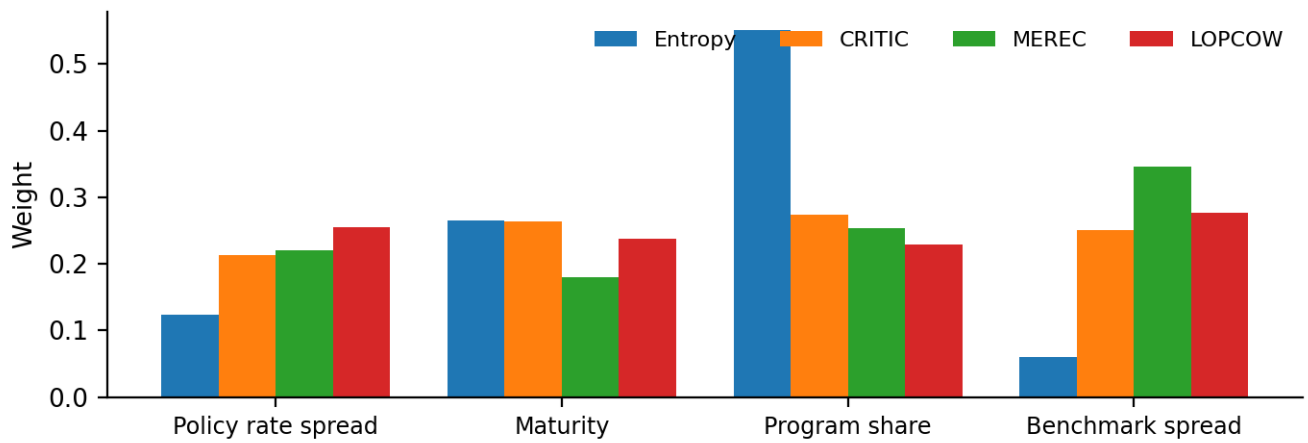


Fig. 4. Objective criterion weights across four schemes

An important analytical feature of the top-ranked group is that placements of half a billion to one and a half billion lira occupy the summit. This pattern stems from the construction of the program share criterion, which captures the strategic substitution role of the certificate channel rather than absolute volume. In the months that the Treasury suspended nominal conventional auctions, the certificate channel was the only auction based funding tap of the sovereign, and a one hundred percent program share records exactly that sole tap dominance. The entropy weighting rewards this strategic role because it discriminates sharply across auctions, and the small absolute size of those placements is a property of the direct sales era rather than a design failure. Decision makers who read the ranking on absolute scale can instead follow the size column directly, where the October 2023 auction of 28.9 billion lira and the November 2018 auction of 3.2 billion lira, both of which rank just outside the leading group, mark the large issuance designs.

Table 5

Top ten and bottom five sovereign sukuk auctions under picture fuzzy TOPSIS

ID	Date	Pol sprd	Mat	Share	B sprd	Size	CC
Panel A. Top ten issuance designs, ranks 1 to 10							
S14	2020-12-08	-1.80	1820	1.0000	missing	0.520	0.8040
S13	2020-08-25	5.35	1456	1.0000	missing	0.547	0.7540
S04	2019-08-20	-4.95	728	1.0000	-370.0	0.847	0.7518
S02	2019-02-12	-6.40	728	1.0000	missing	1.479	0.7471
S15	2021-02-09	-3.10	728	1.0000	missing	1.468	0.7354
S08	2020-03-24	0.91	728	1.0000	missing	0.600	0.7211
S12	2020-07-07	1.25	728	1.0000	missing	1.096	0.7198
S07	2020-02-11	-1.47	728	1.0000	-6.0	2.205	0.7196
S05	2019-12-17	-0.50	728	1.0000	166.0	1.948	0.7071
S01	2018-11-19	-6.10	728	0.7401	-8.0	3.241	0.5498
Panel B. Bottom five issuance designs, ranks 49 to 53							
S53	2025-08-12	-6.18	728	0.0454	-16.0	13.901	0.1745
S22	2022-03-22	10.30	728	0.1594	305.0	4.099	0.1701
S42	2024-05-07	-9.10	728	0.0289	-1.0	4.357	0.1695
S16	2021-07-13	-0.92	728	0.0572	0.0	1.144	0.1658
S23	2022-05-10	8.70	728	0.0692	0.0	2.272	0.1321
ID	Date	CI lower	CI upper	Q	rT	rV	rB
Panel A. Top ten issuance designs, ranks 1 to 10							
S14	2020-12-08	0.7607	0.8468	0.0000	1	1	1
S13	2020-08-25	0.6995	0.8080	0.2637	2	3	2
S04	2019-08-20	0.6903	0.8055	0.2819	3	5	3
S02	2019-02-12	0.6865	0.8037	0.2819	4	6	4

Table 5

Continued

Panel A. Top ten issuance designs, ranks 1 to 10							
S15	2021-02-09	0.6737	0.7934	0.2819	5	7	5
S08	2020-03-24	0.6571	0.7823	0.2819	6	8	6
S12	2020-07-07	0.6558	0.7814	0.2819	7	9	8
S07	2020-02-11	0.6607	0.7804	0.2819	8	10	7
S05	2019-12-17	0.6496	0.7722	0.2819	9	11	9
S01	2018-11-19	0.5159	0.5821	0.5266	10	18	12
Panel B. Bottom five issuance designs, ranks 49 to 53							
S53	2025-08-12	0.1415	0.2077	0.9104	49	49	49
S22	2022-03-22	0.1573	0.1825	0.9929	50	53	52
S42	2024-05-07	0.1307	0.2089	0.9274	51	52	51
S16	2021-07-13	0.1395	0.1900	0.9096	52	48	50
S23	2022-05-10	0.1159	0.1435	0.9175	53	51	53

Note: Pol sprd is the policy rate spread in percentage points. Mat is maturity in days. Share is the monthly borrowing program share. B sprd is the conventional benchmark spread in basis points, with missing cells for auctions without a matched benchmark within one adjacent month. Size is the accepted amount in billion Turkish lira. CC is the picture fuzzy TOPSIS closeness coefficient, with CI lower and CI upper the 2.5th and 97.5th percentiles of one thousand bootstrap resamples of the decision matrix. Q is the picture fuzzy VIKOR compromise index with v of 0.5. r_T , r_V , and r_B denote the rank orders under PF-TOPSIS, PF-VIKOR, and the five-method Borda consensus. The complete evaluation of all fifty three auctions appears in Table A3.

Figure 5 visualizes the leading group with its auction level bootstrap intervals.

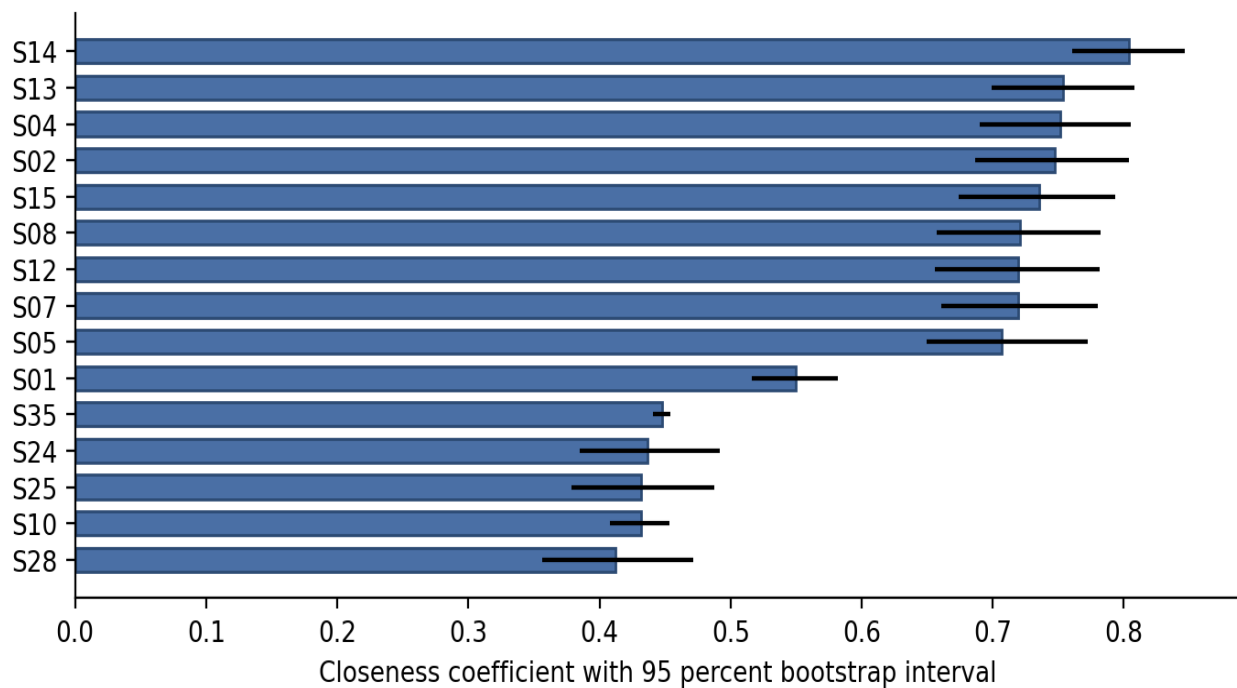


Fig. 5. Top fifteen auctions by picture fuzzy TOPSIS with bootstrap intervals

The picture fuzzy VIKOR ranking aligns closely with the distance-based methods, with a Kendall coefficient of 0.8084 and a Spearman correlation of 0.931, and its leading positions overlap the TOPSIS leading group. This concordance indicates that the composition of the leading group is an intrinsic property of the auction data across both compensatory and regret based paradigms. MARCOS correlates at 0.988 with the distance based methods, and the auction that performs worst on both cost criteria ranks fifty second of fifty three under MARCOS, confirming consistent penalization of high cost issuances across utility ratio and distance metrics. WASPAS and CoCoSo

reproduce this order almost exactly, with Spearman correlations of 0.994 and 0.993 against the TOPSIS ranking. A notable structural cluster emerges within the compromise index. The auctions that carry a full program share and a two year maturity share the same regret on maturity, which is their binding criterion, and therefore cluster within a narrow band of the compromise index. The calibration clamps the normalized performance inside the open unit interval, so no absorbing element arises in the weighted aggregation and the cluster members remain individually distinguishable beyond the fourth decimal of the index. Table 6 reports the full agreement matrix, and Figure 6 maps it.

Table 6

Spearman rank agreement across five methods and concordance statistics

Method	PF-TOPSIS	PF-VIKOR	WASPAS	CoCoSo	MARCOS
Panel A. Pairwise Spearman rank correlations (r_s)					
PF-TOPSIS	1.000	0.931	0.994	0.993	0.988
PF-VIKOR	0.931	1.000	0.937	0.938	0.915
WASPAS	0.994	0.937	1.000	1.000	0.974
CoCoSo	0.993	0.938	1.000	1.000	0.973
MARCOS	0.988	0.915	0.974	0.973	1.000
Panel B. Concordance statistics					
Kendall's τ (PF-TOPSIS vs. PF-VIKOR)	0.8084				
Kendall's concordance W (all 5 methods)	0.9713	$\chi^2 = 252.55$	$df = 52$	$p < 0.001$	

Note: Rank vectors are used throughout ($N = 53$ auctions, $m = 5$ methods). WASPAS and CoCoSo differ by a single adjacent rank swap between S03 and S11, so their correlation equals 0.9999 and rounds to 1.000. The concordance chi-square statistic is computed as $\chi^2 = m(n-1)W$.

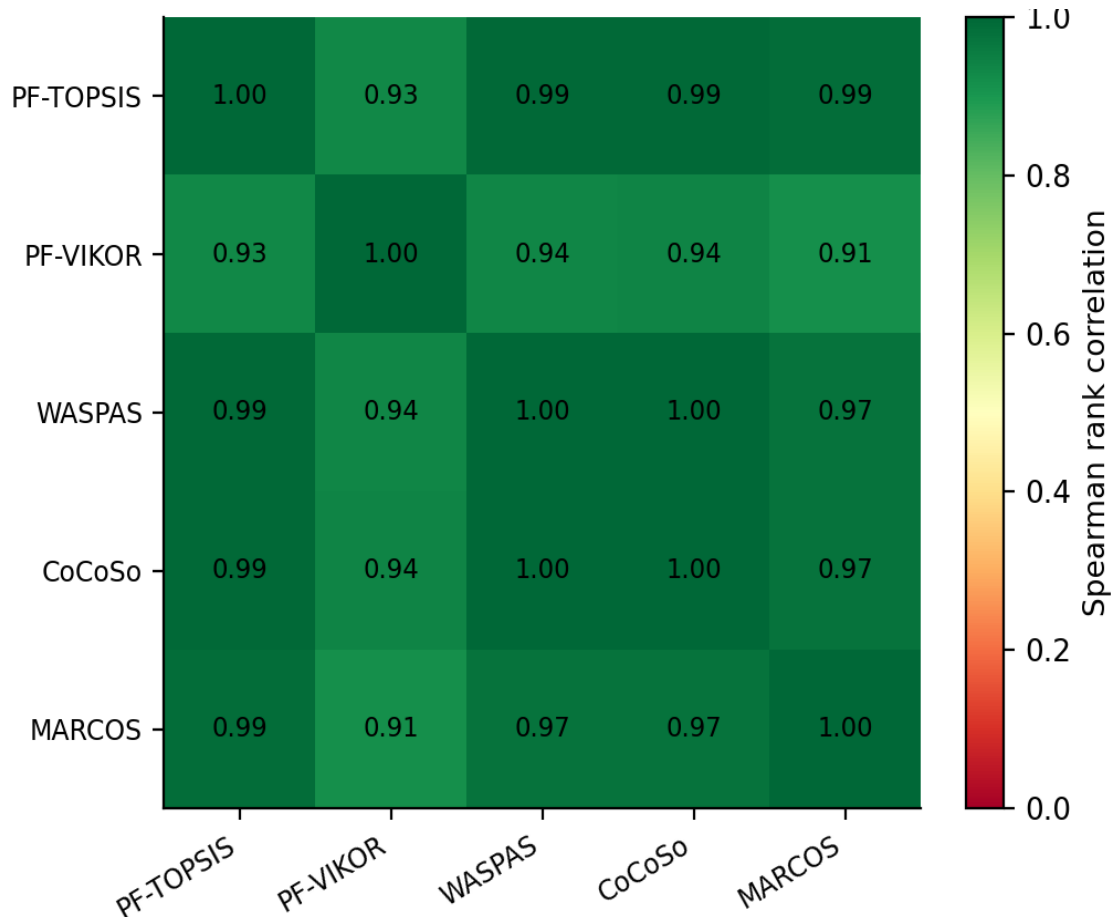


Fig. 6. Pairwise rank agreement across five methods

The Borda consensus across the five methods places the December 2020 five-year auction first, followed by the August 2020 four-year auction, the August 2019 two-year auction, the February 2019 two-year auction, and the February 2021 two-year auction, as reported in the Borda consensus column of Table 5.

6.3. Reading the Ranking Against the Regimes

The policy rate spread criterion shapes the temporal pattern. In the pre tightening era the participation bank clientele absorbed certificates below the monetary anchor, and the auctions that combined that advantage with program dominance rank at the top. After mid 2023 the policy rate rose faster than certificate coupons, the spread narrowed and occasionally turned positive, and the ranking came to rest on maturity and size. This pattern is exactly what preferred habitat theory predicts for a captive investor base with limited arbitrage, and it is the regime adjusted counterpart of the relative cost evidence in the secondary market literature [2, 15, 16].

The policy rate spread requires disciplined reading. Because the anchor is an overnight rate, a wide negative spread can reflect an inverted yield curve rather than an instrument specific advantage. The February 2024 five year auction illustrates the distinction. Its coupon stands 17.4 points below the policy rate of its day, yet only 1 basis point inside the matched five year conventional benchmark, which indicates that the gap prices the expected disinflation over the five year horizon and not a special discount for certificates. The benchmark spread, which matches maturity and month, is the clean measure of the instrument wedge, and the two criteria are kept side by side precisely so that slope and wedge can be separated.

7. Robustness and Additional Tests

Sensitivity of rankings to weighting and aggregation choices is now a standard audit requirement in the multi criteria literature [36], and the battery below follows that standard. Table 7 and Figure 7 collect the tests. The five weighting schemes reproduce the base TOPSIS ordering with Spearman correlations between 0.816 and 0.924 and the base VIKOR ordering with correlations between 0.970 and 0.981, with the standard deviation weights computed on the normalized decision matrix. Halving and doubling the uncertainty scale that drives the refusal grade leaves the TOPSIS ordering intact at correlations of 0.999 and 0.997, and removing the neutral grade entirely or doubling its share moves the correlation no lower than 0.989. Excluding all nine auctions of 2020 leaves the relative ordering of the remaining auctions virtually unaltered (Spearman 1.000), as does excluding the ten auctions with missing benchmark spreads (Spearman 1.000), which indicates that the available case normalization does not distort the rankings. The VIKOR trade off parameter swept from zero to one tracks the base compromise ordering at correlations between 0.833 and 1.000. A rank reversal test that deletes the ten weakest auctions keeps all twenty of the original top twenty inside the reduced top twenty, and the bootstrap confidence intervals of Table 5 place the leader between 0.761 and 0.847 with a clear separation from the rest of the field.

Table 7

Robustness of the rankings under alternative specifications

Panel A. Alternative weighting schemes and rating calibrations		
Specification	Target	Spearman with base
CRITIC weights	PF-TOPSIS	0.883
MEREC weights	PF-TOPSIS	0.834
LOPCOW weights	PF-TOPSIS	0.816
Equal weights	PF-TOPSIS	0.836
Standard deviation weights	PF-TOPSIS	0.924
CRITIC weights	PF-VIKOR	0.978
MEREC weights	PF-VIKOR	0.970

Table 7

Continued

Panel A. Alternative weighting schemes and rating calibrations		
Specification	Target	Spearman with base
LOPCOW weights	PF-VIKOR	0.970
Equal weights	PF-VIKOR	0.972
Standard deviation weights	PF-VIKOR	0.981
Uncertainty scale halved	PF-TOPSIS	0.999
Uncertainty scale doubled	PF-TOPSIS	0.997
Neutral grade removed	PF-TOPSIS	0.989
Neutral grade doubled	PF-TOPSIS	0.993
Panel B. VIKOR trade off parameter sweep		
v	Spearman with base Q	
0.00	0.833	
0.25	0.963	
0.50	1.000	
0.75	0.976	
1.00	0.909	
Panel C. Subsample removal and deletion sensitivity		
Specification	Target	Outcome
All nine auctions of 2020 excluded	PF-TOPSIS	1.000
Ten auctions with missing benchmark excluded	PF-TOPSIS	1.000
Weakest five percent of auctions excluded	PF-TOPSIS	1.000
Weakest ten percent of auctions excluded	PF-TOPSIS	1.000
Weakest twenty percent of auctions excluded	PF-TOPSIS	1.000
Ten weakest auctions excluded, top twenty retention	PF-TOPSIS	20 of 20

Note: Spearman correlations are computed against the baseline PF-TOPSIS ordering in Panels A and C and against the baseline Q ordering in Panel B.

Every reported correlation is at least 0.816, and both removal panels report 1.000, so no specification overturns the ordering. The figure summarizes the same scenarios and shows that the leader holds its position across the entire battery.

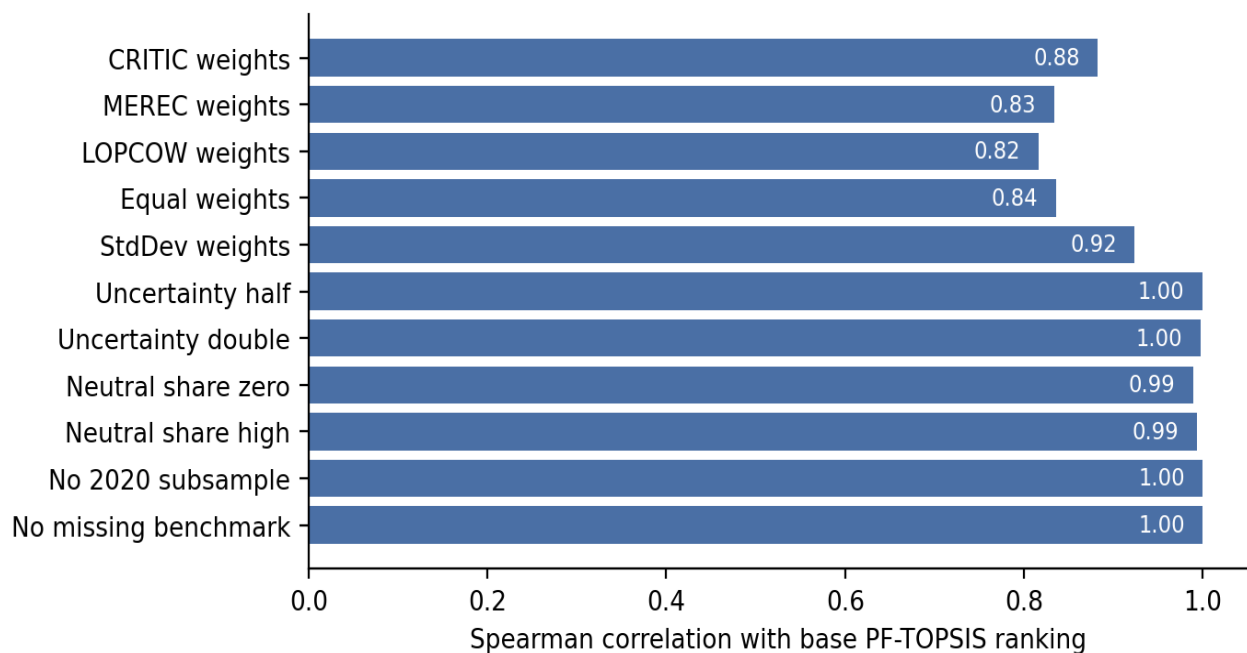


Fig. 7. Robustness of the base ranking under alternative specifications

The thirteen indexed auctions excluded from the main evaluation are examined separately, and Table 8 reports their maturity and size. The September 2025 overnight indexed auction of 80.1 billion lira exceeds the next largest indexed auction by an order of magnitude in nominal size, which confirms that the instrument redesign of late 2025 was a scaling decision rather than a marginal one. Amounts in this table remain nominal and serve only for within subgroup comparison. Evaluation of the indexed segment on cost criteria awaits a longer history and the accumulation of matched conventional benchmarks.

Table 8

Characteristics and volume rankings of index-linked sovereign sukuk auctions

Date	ISIN	Type	Coupon six month	Amount bn TL	Maturity days	Rank by volume
2019-11-05	TRD301024T10	CPI	1.63	1.721	1820	9
2020-04-07	TRD020425T11	CPI	1.70	1.470	1820	10
2020-04-28	TRD251023T18	CPI	0.79	9.460	1274	8
2020-09-22	TRD170925T19	CPI	0.95	0.816	1820	13
2021-04-20	TRD150426T15	CPI	1.43	1.361	1820	11
2021-06-08	TRD280531T12	CPI	1.59	0.951	3640	12
2022-01-25	TRD200127T10	CPI	0.00	13.333	1820	6
2022-04-19	TRD070432T17	CPI	0.00	11.064	3640	7
2024-06-04	TRD020627T17	CPI	1.63	14.220	1092	5
2025-09-08	TRD080927T34	TLREF	21.50	80.074	728	1
2025-10-07	TRD061027T33	TLREF	20.00	38.373	728	2
2025-11-18	TRD171127T13	TLREF	19.00	17.783	728	3
2025-12-16	TRD151227T14	TLREF	18.25	15.045	728	4

Note: CPI denotes consumer price index linked certificates and TLREF denotes certificates indexed to the overnight participation reference rate. The two 2022 CPI placements carry a zero real coupon and pay only the inflation adjustment, which the zero entries record. Amounts are nominal and serve only for within subgroup comparison.

8. Discussion

8.1. Findings Against the Literature

The regime adjusted evidence sharpens rather than overturns the segmentation view of the sukuk literature. Secondary market studies find that sukuk and conventional bonds share macro drivers while retaining idiosyncratic components [2, 15, 16], and this study locates the same segmentation one step earlier in the issuance chain, at the auction itself. Three comparisons carry the argument. The policy rate spread, which averages minus 3.12 points across the sample, is the primary market signature of the captive participation bank clientele that the institutional literature describes [1], and the finding that certificate supply tracks the balance sheet needs of that clientele sits naturally beside evidence that sukuk market development co moves with the capital buffer management of Islamic banks [37]. The inversion of the cost advantage in the early tightening months mirrors the regime dependence that Islamic bank financing exhibits across growth regimes [38] and the sensitivity of sukuk to macroeconomic and geopolitical shocks [39], so the certificate market behaves like the rest of the interest free sector rather than like a conventional funding window. The benchmark spread, which sits near zero on median, indicates that the certificate channel prices as an extension of the conventional curve once maturity and month are matched, which refines the segmentation reading of the Malaysian evidence [6] by showing that segmentation lives in the investor base and not in a permanent yield premium.

The agreement across method families is itself a substantive finding. Across the evaluated models, the distance based, regret based, utility based, and ratio based methods produce orderings that correlate between 0.915 and 0.994 [23–26], which indicates that the ranking is a property of the auction data rather than of any single aggregation philosophy, and the concordance coefficient of

0.9713 reported in Table 6 formalizes the point. Theoretically, the result is what preferred habitat reasoning predicts. A captive clientele absorbs instruments on terms set by its own balance sheet constraint, so auction outcomes cluster into regime specific design families rather than along a single quality gradient, and both compensatory and regret based aggregations recover the same families from different directions. The residual diversity in the treatment of the long dated 2022 auctions is reported explicitly in Table 6 rather than averaged away, and the consensus ordering reconciles it through the Borda count.

8.2. Implications for Debt Management

Three practical lessons follow. Regime adjusted benchmarking is not optional in high inflation economies. An evaluation that compares nominal coupons and nominal sizes across years confuses the price level with design quality, and the relative criteria of this study remove that confusion. The certificate channel also funds cheapest relative to the monetary anchor when the participation bank balance sheets are most constrained, which suggests timing certificate supply to the liquidity cycle of that clientele rather than to the conventional auction calendar. The data give this recommendation a concrete shape. The sole tap auctions of the direct sales era, which carried the entire monthly program and funded below the anchor, occurred exactly when conventional auctions were suspended and participation banks were the only balance sheets available to the sovereign, so a supply calendar that reads the liquidity indicators of the participation banking system would have placed the same auctions without waiting for the conventional program to pause. The advantage is measurable rather than rhetorical, of the order of several percentage points per year on the placements that the evaluation identifies as dominant. The overnight indexed redesign of late 2025 transfers the program to a new evaluation regime, and the framework accommodates the shift by construction once a matched benchmark history accumulates. The default experience of sovereign sukuk in other jurisdictions warns against reading a funding cost advantage as a permanent feature of the instrument, so the practical value of the framework lies in keeping the evaluation live as the instrument mix changes rather than in the ranking of any single year. For debt offices that adopt it, the program shares column of the evaluation doubles as an early warning indicator, because a falling share signals that the certificate channel is losing its role in the funding plan before the cost criteria move.

8.3. Limitations

Five limitations qualify the findings. The evaluation adopts the issuer perspective, and investor welfare, secondary market liquidity, and the asset side of the special purpose vehicle are outside the criterion set. The conventional benchmark is interpolated from primary market auctions, and the direct sales era of 2020 and early 2021 leaves ten auctions without a match inside the one month window in either direction, which is why those cells are treated by available case normalization and re estimated by deletion with no change in the ranking. The published coupon is compared rather than the realized yield to maturity because auction level issue prices are not disclosed for direct sales. The thirteen indexed auctions are excluded from the main ranking, which truncates the largest and most recent segment of the program. The program share replaces a consumer price deflator because a consistent monthly price index could not be combined with the auction record at this frequency. The cells in which the certificate channel is the only auction tap of the month concentrate in the direct sales era and carries a share of one by construction, which rewards sole tap dominance rather than absolute scale. This specification is designed to evaluate whether the certificate channel carried the funding plan, and decision makers who read the ranking on absolute scale can follow the size column directly as noted in Section 6.2. The framework also abstracts from default risk, which the

sovereign sukuk record shows to be material even for interest free instruments [40], and from the bidder side of the auctions.

9. Conclusions

This study ranked every domestic fixed rate sovereign sukuk auction executed by the Turkish Treasury between 2018 and 2025 using a regime adjusted picture fuzzy multi criteria framework in which every rating is calibrated from a published auction outcome and every hesitation grade equals estimation uncertainty. The five methods place the direct sale placements of 2019 to early 2021 that carried the entire monthly auction funding program, at the top of the ranking, and the five methods agree pairwise at Spearman correlations of 0.915 or better, with a Kendall coefficient of 0.8084 between the two picture fuzzy procedures. Every substantive claim survives five weighting schemes, uncertainty scale perturbations in both directions, the removal of the year 2020 and of every auction with a missing benchmark, a trade off parameter sweep, rank reversal tests, and one thousand bootstrap resamples. The framework is transparent, reproducible from public announcements, and portable to any sovereign issuance program that publishes auction terms.

Appendix

Table A1

Full population of domestic lease certificate auctions 2018 to 2025

ID	Date	ISIN	Type	Coupon six month	Amount bn TL	Maturity days
S01	2018-11-19	TRD211120T18	FIXED	8.95	3.241	728
S02	2019-02-12	TRD100221T17	FIXED	8.8	1.479	728
S03	2019-06-18	TRD160621T17	FIXED	10.55	1.606	728
S04	2019-08-20	TRD180821T13	FIXED	7.4	0.847	728
I01	2019-11-05	TRD301024T10	CPI	1.63	1.721	1820
S05	2019-12-17	TRD151221T10	FIXED	5.75	1.948	728
S06	2020-01-28	TRD260122T19	FIXED	4.88	2.926	728
S07	2020-02-11	TRD090222T19	FIXED	4.89	2.205	728
S08	2020-03-24	TRD230322T10	FIXED	5.33	0.600	728
I02	2020-04-07	TRD020425T11	CPI	1.7	1.470	1820
I03	2020-04-28	TRD251023T18	CPI	0.79	9.460	1274
S09	2020-04-28	TRD281020T26	FIXED	3.82	5.705	182
S10	2020-05-12	TRD110522T12	FIXED	4.7	6.457	728
S11	2020-05-12	TRD111120T16	FIXED	3.83	5.354	182
S12	2020-07-07	TRD060722T17	FIXED	4.75	1.096	728
S13	2020-08-25	TRD210824T15	FIXED	6.8	0.547	1456
I04	2020-09-22	TRD170925T19	CPI	0.95	0.816	1820
S14	2020-12-08	TRD031225T10	FIXED	6.6	0.520	1820
S15	2021-02-09	TRD080223T19	FIXED	6.95	1.468	728
I05	2021-04-20	TRD150426T15	CPI	1.43	1.361	1820
I06	2021-06-08	TRD280531T12	CPI	1.59	0.951	3640
S16	2021-07-13	TRD120723T18	FIXED	9.04	1.144	728
S17	2021-08-17	TRD160823T13	FIXED	8.9	0.922	728
S18	2021-09-21	TRD160926T19	FIXED	8.4	0.725	1820
S19	2021-10-19	TRD181023T17	FIXED	9.05	1.915	728
S20	2021-12-14	TRD131223T10	FIXED	10.16	2.993	728
I07	2022-01-25	TRD200127T10	CPI	0.0	13.333	1820
S21	2022-02-15	TRD140224T10	FIXED	10.1	5.561	728
S22	2022-03-22	TRD200324T29	FIXED	12.15	4.099	728
I08	2022-04-19	TRD070432T17	CPI	0.0	11.064	3640
S23	2022-05-10	TRD080524T15	FIXED	11.35	2.272	728
S24	2022-07-05	TRD230632T15	FIXED	9.04	8.240	3640
S25	2022-08-16	TRD040832T16	FIXED	8.07	10.290	3640

Table A1

Continued

ID	Date	ISIN	Type	Coupon six month	Amount bn TL	Maturity days
S26	2022-09-13	TRD080927T18	FIXED	5.09	19.718	1820
S27	2022-10-11	TRD061027T17	FIXED	5.23	11.484	1820
S28	2022-11-08	TRD271032T15	FIXED	5.86	6.892	3640
S29	2023-01-24	TRD190128T12	FIXED	4.79	14.009	1820
S30	2023-02-21	TRD160228T14	FIXED	4.64	9.946	1820
S31	2023-03-07	TRD230233T18	FIXED	5.71	5.413	3640
S32	2023-06-20	TRD140628T12	FIXED	8.62	12.086	1820
S33	2023-08-08	TRD020828T14	FIXED	9.79	27.148	1820
S34	2023-09-19	TRD070933T11	FIXED	13.19	9.898	3640
S35	2023-10-17	TRD111028T19	FIXED	14.26	28.927	1820
S36	2023-11-14	TRD081128T13	FIXED	16.48	3.567	1820
S37	2023-12-12	TRD061228T14	FIXED	14.28	10.000	1820
S38	2024-01-23	TRD170129T13	FIXED	14.34	5.856	1820
S39	2024-02-20	TRD140229T15	FIXED	13.79	3.570	1820
S40	2024-03-19	TRD140329T14	FIXED	15.0	3.562	1820
S41	2024-04-16	TRD150426T49	FIXED	20.23	5.684	728
S42	2024-05-07	TRD060526T15	FIXED	20.45	4.357	728
I09	2024-06-04	TRD020627T17	CPI	1.63	14.220	1092
S43	2024-07-23	TRD220726T13	FIXED	19.27	12.000	728
S44	2024-08-13	TRD120826T14	FIXED	18.85	3.478	728
S45	2024-09-17	TRD160926T35	FIXED	18.72	4.464	728
S46	2024-10-15	TRD141026T18	FIXED	19.54	12.533	728
S47	2024-11-12	TRD111126T10	FIXED	18.5	12.080	728
S48	2024-12-17	TRD161226T14	FIXED	18.5	1.469	728
S49	2025-02-11	TRD100227T11	FIXED	17.36	7.298	728
S50	2025-04-08	TRD070427T14	FIXED	21.31	22.060	728
S51	2025-06-17	TRD160627T11	FIXED	19.98	15.126	728
S52	2025-07-21	TRD170730T14	FIXED	16.68	23.773	1820
S53	2025-08-12	TRD110827T14	FIXED	18.41	13.901	728
I10	2025-09-08	TRD080927T34	TLREF	21.5	80.074	728
I11	2025-10-07	TRD061027T33	TLREF	20.0	38.373	728
I12	2025-11-18	TRD171127T13	TLREF	19.0	17.783	728
I13	2025-12-16	TRD151227T14	TLREF	18.25	15.045	728

Note: S codes identify the fifty three fixed rate auctions and I codes the thirteen index linked auctions. FIXED denotes fixed rate certificates, CPI consumer price index linked certificates, and TLREF certificates indexed to the overnight participation reference rate. Amounts are nominal accepted amounts in billion Turkish lira.

Table A2

Regime indicators and criterion construction by auction

ID	Date	Policy rate	Annual coupon	Policy spread	Program share
S01	2018-11-19	24.0	17.90	-6.10	0.7401
S02	2019-02-12	24.0	17.60	-6.40	1.0000
S03	2019-06-18	24.0	21.10	-2.90	0.2342
S04	2019-08-20	19.75	14.80	-4.95	1.0000
S05	2019-12-17	12.0	11.50	-0.50	1.0000
S06	2020-01-28	11.25	9.76	-1.49	0.4196
S07	2020-02-11	11.25	9.78	-1.47	1.0000
S08	2020-03-24	9.75	10.66	0.91	1.0000
S09	2020-04-28	8.75	7.64	-1.11	0.3430
S10	2020-05-12	8.75	9.40	0.65	0.5467
S11	2020-05-12	8.75	7.66	-1.09	0.4533
S12	2020-07-07	8.25	9.50	1.25	1.0000
S13	2020-08-25	8.25	13.60	5.35	1.0000

Table A2
Continued

ID	Date	Policy rate	Annual coupon	Policy spread	Program share
S14	2020-12-08	15.0	13.20	-1.80	1.0000
S15	2021-02-09	17.0	13.90	-3.10	1.0000
S16	2021-07-13	19.0	18.08	-0.92	0.0572
S17	2021-08-17	19.0	17.80	-1.20	0.0705
S18	2021-09-21	19.0	16.80	-2.20	0.0296
S19	2021-10-19	18.0	18.10	0.10	0.0852
S20	2021-12-14	15.0	20.32	5.32	0.3606
S21	2022-02-15	14.0	20.20	6.20	0.1681
S22	2022-03-22	14.0	24.30	10.30	0.1594
S23	2022-05-10	14.0	22.70	8.70	0.0692
S24	2022-07-05	14.0	18.08	4.08	0.2045
S25	2022-08-16	14.0	16.14	2.14	0.1852
S26	2022-09-13	13.0	10.18	-2.82	0.2949
S27	2022-10-11	12.0	10.46	-1.54	0.2017
S28	2022-11-08	10.5	11.72	1.22	0.1494
S29	2023-01-24	9.0	9.58	0.58	0.1658
S30	2023-02-21	9.0	9.28	0.28	0.1590
S31	2023-03-07	8.5	11.42	2.92	0.0724
S32	2023-06-20	8.5	17.24	8.74	0.1440
S33	2023-08-08	17.5	19.58	2.08	0.2588
S34	2023-09-19	25.0	26.38	1.38	0.1046
S35	2023-10-17	30.0	28.52	-1.48	0.4023
S36	2023-11-14	35.0	32.96	-2.04	0.0529
S37	2023-12-12	40.0	28.56	-11.44	0.1102
S38	2024-01-23	42.5	28.68	-13.82	0.0498
S39	2024-02-20	45.0	27.58	-17.42	0.0419
S40	2024-03-19	45.0	30.00	-15.00	0.0509
S41	2024-04-16	50.0	40.46	-9.54	0.0593
S42	2024-05-07	50.0	40.90	-9.10	0.0289
S43	2024-07-23	50.0	38.54	-11.46	0.0916
S44	2024-08-13	50.0	37.70	-12.30	0.0465
S45	2024-09-17	50.0	37.44	-12.56	0.0332
S46	2024-10-15	50.0	39.08	-10.92	0.0992
S47	2024-11-12	50.0	37.00	-13.00	0.0852
S48	2024-12-17	50.0	37.00	-13.00	0.0123
S49	2025-02-11	45.0	34.72	-10.28	0.0429
S50	2025-04-08	42.5	42.62	0.12	0.1094
S51	2025-06-17	46.0	39.96	-6.04	0.0610
S52	2025-07-21	46.0	33.36	-12.64	0.0949
S53	2025-08-12	43.0	36.82	-6.18	0.0454
ID	Date	Accepted amount bn TL	Monthly conventional volume bn TL	Matched benchmark yield	
S01	2018-11-19	3.241	1.138	17.98	
S02	2019-02-12	1.479	0.000	missing	
S03	2019-06-18	1.606	5.250	20.79	
S04	2019-08-20	0.847	0.000	18.5	
S05	2019-12-17	1.948	0.000	9.84	
S06	2020-01-28	2.926	4.047	9.84	
S07	2020-02-11	2.205	0.000	9.84	
S08	2020-03-24	0.600	0.000	missing	
S09	2020-04-28	5.705	0.000	missing	
S10	2020-05-12	6.457	0.000	missing	
S11	2020-05-12	5.354	0.000	missing	

Table A2
Continued

ID	Date	Accepted amount bn TL	Monthly conventional volume bn TL	Matched benchmark yield
S12	2020-07-07	1.096	0.000	missing
S13	2020-08-25	0.547	0.000	missing
S14	2020-12-08	0.520	0.000	missing
S15	2021-02-09	1.468	0.000	missing
S16	2021-07-13	1.144	18.852	18.08
S17	2021-08-17	0.922	12.155	18.0
S18	2021-09-21	0.725	23.803	16.96
S19	2021-10-19	1.915	20.555	18.7
S20	2021-12-14	2.993	5.306	20.33
S21	2022-02-15	5.561	27.513	missing
S22	2022-03-22	4.099	21.620	21.25
S23	2022-05-10	2.272	30.542	22.7
S24	2022-07-05	8.240	32.049	18.13
S25	2022-08-16	10.290	45.277	16.14
S26	2022-09-13	19.718	47.151	10.3
S27	2022-10-11	11.484	45.450	10.45
S28	2022-11-08	6.892	39.233	11.73
S29	2023-01-24	14.009	70.482	9.76
S30	2023-02-21	9.946	52.613	9.29
S31	2023-03-07	5.413	69.368	11.36
S32	2023-06-20	12.086	71.833	17.25
S33	2023-08-08	27.148	77.743	19.59
S34	2023-09-19	9.898	84.726	26.38
S35	2023-10-17	28.927	42.970	28.54
S36	2023-11-14	3.567	63.854	32.96
S37	2023-12-12	10.000	80.731	28.56
S38	2024-01-23	5.856	111.785	28.7
S39	2024-02-20	3.570	81.647	27.59
S40	2024-03-19	3.562	66.407	27.59
S41	2024-04-16	5.684	90.091	40.46
S42	2024-05-07	4.357	146.491	40.91
S43	2024-07-23	12.000	119.060	38.28
S44	2024-08-13	3.478	71.379	37.43
S45	2024-09-17	4.464	130.128	37.43
S46	2024-10-15	12.533	113.820	39.08
S47	2024-11-12	12.080	129.769	39.34
S48	2024-12-17	1.469	117.675	39.34
S49	2025-02-11	7.298	162.824	34.72
S50	2025-04-08	22.060	179.664	42.79
S51	2025-06-17	15.126	232.941	40.16
S52	2025-07-21	23.773	226.801	33.37
S53	2025-08-12	13.901	292.143	36.98

Note: Policy rate is the central bank one week repo rate in effect on the auction day, in percent. Policy spread is the annual coupon minus the policy rate, in percentage points. Monthly conventional volume is the total accepted nominal conventional bond and bill amount of the auction month. The matched benchmark yield is the maturity matched conventional auction yield in percent, with missing cells for the ten auctions without a match within one adjacent month.

Table A3
Complete evaluation of the fifty three fixed rate auctions

ID	Date	Pol sprd	Mat	Share	B sprd	Size	CC	Q	WASP
S01	2018-11-19	-6.10	728	0.7401	-8.0	3.241	0.5498	0.5266	0.5176
S02	2019-02-12	-6.40	728	1.0000	missing	1.479	0.7471	0.2819	0.6369
S03	2019-06-18	-2.90	728	0.2342	30.5	1.606	0.2943	0.6954	0.2510
S04	2019-08-20	-4.95	728	1.0000	-370.0	0.847	0.7518	0.2819	0.6575
S05	2019-12-17	-0.50	728	1.0000	166.0	1.948	0.7071	0.2819	0.5869
S06	2020-01-28	-1.49	728	0.4196	-8.0	2.926	0.3856	0.6427	0.3469
S07	2020-02-11	-1.47	728	1.0000	-6.0	2.205	0.7196	0.2819	0.6118
S08	2020-03-24	0.91	728	1.0000	missing	0.600	0.7211	0.2819	0.6018
S09	2020-04-28	-1.11	182	0.3430	missing	5.705	0.2914	0.9171	0.2085
S10	2020-05-12	0.65	728	0.5467	missing	6.457	0.4318	0.6134	0.4014
S11	2020-05-12	-1.09	182	0.4533	missing	5.354	0.3453	0.8806	0.2510
S12	2020-07-07	1.25	728	1.0000	missing	1.096	0.7198	0.2819	0.5998
S13	2020-08-25	5.35	1456	1.0000	missing	0.547	0.7540	0.2637	0.6595
S14	2020-12-08	-1.80	1820	1.0000	missing	0.520	0.8040	0.0000	0.7460
S15	2021-02-09	-3.10	728	1.0000	missing	1.468	0.7354	0.2819	0.6222
S16	2021-07-13	-0.92	728	0.0572	0.0	1.144	0.1658	0.9096	0.1311
S17	2021-08-17	-1.20	728	0.0705	-20.0	0.922	0.1787	0.8836	0.1437
S18	2021-09-21	-2.20	1820	0.0296	-16.0	0.725	0.2219	0.8944	0.1642
S19	2021-10-19	0.10	728	0.0852	-59.9	1.915	0.1877	0.8586	0.1531
S20	2021-12-14	5.32	728	0.3606	-1.0	2.993	0.3314	0.6766	0.2864
S21	2022-02-15	6.20	728	0.1681	missing	5.561	0.2070	0.7719	0.1826
S22	2022-03-22	10.30	728	0.1594	305.0	4.099	0.1701	0.9929	0.1156
S23	2022-05-10	8.70	728	0.0692	0.0	2.272	0.1321	0.9175	0.1073
S24	2022-07-05	4.08	3640	0.2045	-5.0	8.240	0.4363	0.2497	0.3859
S25	2022-08-16	2.14	3640	0.1852	0.0	10.290	0.4321	0.2716	0.3807
S26	2022-09-13	-2.82	1820	0.2949	-12.0	19.718	0.4009	0.4979	0.3744
S27	2022-10-11	-1.54	1820	0.2017	1.0	11.484	0.3438	0.6250	0.3076
S28	2022-11-08	1.22	3640	0.1494	-1.0	6.892	0.4123	0.3139	0.3562
S29	2023-01-24	0.58	1820	0.1658	-17.7	14.009	0.3146	0.6804	0.2758
S30	2023-02-21	0.28	1820	0.1590	-1.0	9.946	0.3104	0.6910	0.2709
S31	2023-03-07	2.92	3640	0.0724	6.0	5.413	0.3489	0.4134	0.2789
S32	2023-06-20	8.74	1820	0.1440	-1.0	12.086	0.2620	0.8332	0.2183
S33	2023-08-08	2.08	1820	0.2588	-1.0	27.148	0.3640	0.5564	0.3303
S34	2023-09-19	1.38	3640	0.1046	0.0	9.898	0.3800	0.3703	0.3164
S35	2023-10-17	-1.48	1820	0.4023	-2.0	28.927	0.4478	0.3728	0.4324
S36	2023-11-14	-2.04	1820	0.0529	0.0	3.567	0.2401	0.8550	0.1895
S37	2023-12-12	-11.44	1820	0.1102	0.0	10.000	0.3168	0.7227	0.2698
S38	2024-01-23	-13.82	1820	0.0498	-2.0	5.856	0.2801	0.8010	0.2181
S39	2024-02-20	-17.42	1820	0.0419	-1.0	3.570	0.2917	0.4712	0.2180
S40	2024-03-19	-15.00	1820	0.0509	241.0	3.562	0.2719	0.7959	0.2052
S41	2024-04-16	-9.54	728	0.0593	0.0	5.684	0.1968	0.8709	0.1559
S42	2024-05-07	-9.10	728	0.0289	-1.0	4.357	0.1695	0.9274	0.1260
S43	2024-07-23	-11.46	728	0.0916	26.0	12.000	0.2284	0.8057	0.1852
S44	2024-08-13	-12.30	728	0.0465	27.0	3.478	0.1954	0.8755	0.1500
S45	2024-09-17	-12.56	728	0.0332	1.0	4.464	0.1864	0.8947	0.1390
S46	2024-10-15	-10.92	728	0.0992	0.0	12.533	0.2335	0.7951	0.1909
S47	2024-11-12	-13.00	728	0.0852	-234.0	12.080	0.2427	0.7749	0.1989
S48	2024-12-17	-13.00	728	0.0123	-234.0	1.469	0.1813	0.9008	0.1255
S49	2025-02-11	-10.28	728	0.0429	0.0	7.298	0.1858	0.8952	0.1431
S50	2025-04-08	0.12	728	0.1094	-17.0	22.060	0.2039	0.8225	0.1677
S51	2025-06-17	-6.04	728	0.0610	-20.0	15.126	0.1872	0.8830	0.1493
S52	2025-07-21	-12.64	1820	0.0949	-1.0	23.773	0.3104	0.7381	0.2598
S53	2025-08-12	-6.18	728	0.0454	-16.0	13.901	0.1745	0.9104	0.1358

Table A3
Continued

ID	Date	CoCo	MARC	rT	rV	rW	rC	rM	rB
S01	2018-11-19	0.6931	0.5534	10	18	10	10	10	12
S02	2019-02-12	0.8523	0.7005	4	6	4	4	4	4
S03	2019-06-18	0.3365	0.2563	28	26	28	27	32	29
S04	2019-08-20	0.8797	0.7240	3	5	3	3	2	3
S05	2019-12-17	0.7850	0.6570	9	11	9	9	9	9
S06	2020-01-28	0.4650	0.3560	17	22	17	17	19	18
S07	2020-02-11	0.8185	0.6765	8	10	6	6	6	7
S08	2020-03-24	0.8050	0.6684	6	8	7	7	7	6
S09	2020-04-28	0.2776	0.2727	30	50	32	32	30	35
S10	2020-05-12	0.5378	0.4190	14	20	12	12	14	14
S11	2020-05-12	0.3342	0.3335	21	41	27	28	21	28
S12	2020-07-07	0.8024	0.6669	7	9	8	8	8	8
S13	2020-08-25	0.8831	0.7042	2	3	2	2	3	2
S14	2020-12-08	1.0000	0.7632	1	1	1	1	1	1
S15	2021-02-09	0.8325	0.6860	5	7	5	5	5	5
S16	2021-07-13	0.1752	0.1524	52	48	49	49	51	50
S17	2021-08-17	0.1921	0.1628	48	43	45	45	50	47
S18	2021-09-21	0.2183	0.2271	38	44	40	40	36	39
S19	2021-10-19	0.2049	0.1687	43	38	42	42	49	43
S20	2021-12-14	0.3839	0.2928	23	23	21	21	26	22
S21	2022-02-15	0.2449	0.1853	39	29	38	38	44	38
S22	2022-03-22	0.1545	0.1327	50	53	52	52	52	52
S23	2022-05-10	0.1436	0.1168	53	51	53	53	53	53
S24	2022-07-05	0.5162	0.4335	12	2	13	13	11	10
S25	2022-08-16	0.5090	0.4309	13	4	14	14	12	11
S26	2022-09-13	0.5020	0.3762	16	17	15	15	17	16
S27	2022-10-11	0.4122	0.3179	22	21	20	20	22	21
S28	2022-11-08	0.4759	0.4152	15	12	16	16	15	15
S29	2023-01-24	0.3694	0.2904	25	24	23	23	27	23
S30	2023-02-21	0.3628	0.2864	27	25	24	24	29	25
S31	2023-03-07	0.3714	0.3646	20	15	22	22	18	20
S32	2023-06-20	0.2921	0.2410	33	36	29	29	34	32
S33	2023-08-08	0.4429	0.3337	19	19	18	18	20	19
S34	2023-09-19	0.4221	0.3897	18	13	19	19	16	17
S35	2023-10-17	0.5800	0.4288	11	14	11	11	13	13
S36	2023-11-14	0.2526	0.2379	35	37	36	36	35	36
S37	2023-12-12	0.3606	0.3109	24	27	25	25	23	24
S38	2024-01-23	0.2904	0.2881	31	33	30	30	28	30
S39	2024-02-20	0.2899	0.2995	29	16	31	31	25	27
S40	2024-03-19	0.2732	0.2724	32	32	33	33	31	31
S41	2024-04-16	0.2080	0.1915	41	39	41	41	41	41
S42	2024-05-07	0.1676	0.1728	51	52	50	50	47	51
S43	2024-07-23	0.2474	0.2155	37	34	37	37	38	37
S44	2024-08-13	0.1999	0.1941	42	40	43	43	40	42
S45	2024-09-17	0.1849	0.1902	45	45	47	47	42	45
S46	2024-10-15	0.2552	0.2196	36	31	35	35	37	34
S47	2024-11-12	0.2654	0.2417	34	30	34	34	33	33
S48	2024-12-17	0.1660	0.2014	47	47	51	51	39	48
S49	2025-02-11	0.1906	0.1857	46	46	46	46	43	46
S50	2025-04-08	0.2245	0.1782	40	35	39	39	46	40
S51	2025-06-17	0.1994	0.1788	44	42	44	44	45	44
S52	2025-07-21	0.3470	0.3078	26	28	26	26	24	26
S53	2025-08-12	0.1811	0.1704	49	49	48	48	48	49

Note: Abbreviations are as defined in Tables 5 and 6. ISIN codes appear in Table A1. Missing benchmark cells indicate auctions without a matched conventional benchmark within one adjacent month.

Acknowledgement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The author declares no conflicts of interest.

References

- [1] Bekâr, A. G. (2022). Kamu finansman aracı olarak kira sertifikası uygulaması ve Türkiye açısından değerlendirilmesi. In H. Karadal, İ. Erdoğan Tarakçı, R. Aslan, & E. Dinçer (Eds.), *İşletme ve İktisat Araştırmaları* (pp. 29–57). Efe Akademik Yayıncılık.
- [2] Balli, F., Ghassan, H., & Al Jeeфри, E. H. (2021). Sukuk and bond spreads. *Journal of Economics and Finance*, 45(3), 529-543. <https://doi.org/10.1007/s12197-021-09545-9>
- [3] Barro, R. J. (1979). On the determination of the public debt. *Journal of Political Economy*, 87(5), 940-971. <https://doi.org/10.1086/260807>
- [4] Culbertson, J. M. (1957). The term structure of interest rates. *The Quarterly Journal of Economics*, 71(4), 485-517. <https://doi.org/10.2307/1885708>
- [5] Modigliani, F., & Sutch, R. (1966). Innovations in interest rate policy. *American Economic Review*, 56(1/2), 178-197.
- [6] Asmuni, N. H., & Tan, K. S. (2020). Exploring the yield spread between sukuk and conventional bonds in Malaysia. *Journal of Emerging Market Finance*, 20(2), 165-191. <https://doi.org/10.1177/0972652720969519>
- [7] Kannadasan, T. N., & Polisetty, A. (2025). Emerging trends and applications of fuzzy decision-making techniques in finance. *Cogent Business & Management*, 12(1), 2590878. <https://doi.org/10.1080/23311975.2025.2590878>
- [8] Cuong, B. C. (2014). Picture fuzzy sets. *Journal of Computer Science and Cybernetics*, 30(4), 409-420. <https://doi.org/10.15625/1813-9663/30/4/5032>
- [9] Kutlu Gündoğdu, F., & Kahraman, C. (2019). A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets. *Engineering Applications of Artificial Intelligence*, 85, 307-323. <https://doi.org/10.1016/j.engappai.2019.06.003>
- [10] Das, P., Ghate, C., & Halder, S. (2025). The maturity structure of public debt: A granular approach using Indian data. *Handbook of Statistics*, 52, 319-351. <https://doi.org/10.1016/bs.host.2025.04.008>
- [11] Demirtaş, T. (2026). Central bank liquidity management instruments in Islamic banking systems: A comparative analysis. *American Journal of Industrial and Business Management*, 16(8), 848-878. <https://doi.org/10.4236/ajibm.2026.168045>
- [12] Capen, E. C., Clapp, R. V., & Campbell, W. M. (1971). Competitive bidding in high-risk situations. *Journal of Petroleum Technology*, 23(6), 641-653. <https://doi.org/10.2118/2993-pa>
- [13] Milgrom, P. R., & Weber, R. J. (1982). A theory of auctions and competitive bidding. *Econometrica*, 50(5), 1089-1122. <https://doi.org/10.2307/1911865>
- [14] Spence, M. (1973). Job market signaling. *The Quarterly Journal of Economics*, 87(3), 355-374. <https://doi.org/10.2307/1882010>
- [15] Balli, F., Billah, M. B., Balli, H. O., & Gregory-Allen, R. (2020). Economic uncertainties, macroeconomic announcements and sukuk spreads. *Applied Economics*, 52(35), 3748-3769. <https://doi.org/10.1080/00036846.2020.1721424>
- [16] Saeed, A., Elnahass, M., Izzeldin, M., & Tsionas, M. G. (2021). Yield spread determinants of sukuk and conventional bonds. *Economic Modelling*, 105, 105664. <https://doi.org/10.1016/j.econmod.2021.105664>
- [17] Low, K. H., Md Noman, A. H., & Wan Ahmad, W. M. (2025). The influence of ESG performance on yield spreads, a comparative study of sukuk and conventional bonds. *Sustainability*, 17(8), 3547. <https://doi.org/10.3390/su17083547>
- [18] Musa, K., Zakaria, N. B., Ghapar, F., & Choudhury, M. (2026). An empirical investigation of the macroeconomic factors and growth of the sovereign sukuk market. *Journal of Islamic Accounting and Business Research*, 1-23. <https://doi.org/10.1108/jiabr-02-2025-0116>
- [19] Noordin, N. H. (2026). Trends and determinants of sustainability sukuk issuance: Evidence from global markets. *Journal of Islamic Monetary Economics and Finance*, 12(3), 405-436. <https://doi.org/10.21098/jimf.v12i3.3341>
- [20] Khalifah, M. H., & Aslan, H. (2025). Sukuk and sustainable finance. In *Islamic Green Finance* (pp. 132-174). Routledge. <https://doi.org/10.4324/9781003540403-11>

- [21] Barukab, O., Abdullah, S., Ashraf, S., Arif, M., & Khan, S. A. (2019). A new approach to fuzzy TOPSIS method based on entropy measure under spherical fuzzy environment. *Entropy*, 21(12), 1231. <https://doi.org/10.3390/e21121231>
- [22] Nwokoro, C. O., & Ejegwa, P. A. (2025). A decade of picture fuzzy sets in multi-criteria decision-making: A comprehensive review. *Knowledge and Decision Systems with Applications*, 1, 145-164. <https://doi.org/10.59543/kadsa.v1i.14051>
- [23] Jin, J., Li, Q., Cai, L., Wang, H., & Pamucar, D. (2026). A novel picture fuzzy entropy measure and its application to scenic spot evaluation. *Applied Soft Computing*, 188, 116351. <https://doi.org/10.1016/j.asoc.2026.116351>
- [24] Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2012). Optimization of weighted aggregated sum product assessment. *Elektronika ir Elektrotechnika*, 122(6), 3-6. <https://doi.org/10.5755/j01.eee.122.6.1810>
- [25] Yazdani, M., Zarate, P., Zavadskas, E. K., & Turskis, Z. (2019). A combined compromise solution method for multi-criteria decision-making problems. *Management Decision*, 57(9), 2501-2519. <https://doi.org/10.1108/md-05-2017-0458>
- [26] Stevic, Z., Pamucar, D., Puska, A., & Chatterjee, P. (2020). Sustainable supplier selection in healthcare industries using a novel MARCOS. *Computers & Industrial Engineering*, 140, 106231. <https://doi.org/10.1016/j.cie.2019.106231>
- [27] Kaur, M. (2025). Fuzzy TOPSIS in FinTech: A decision-making framework for financial performance. In 2025 IEEE 2nd International Conference on Sustainable Computing and Data Communication (pp. 1-19). <https://doi.org/10.1109/incowoco68239.2025.11407171>
- [28] Duymaz, Ş., Güneri, B., & Delen, D. (2026). A multi-criteria decision-making approach to financial performance analysis. *Journal of Soft Computing and Decision Analytics*, 4(1), 1-15. <https://doi.org/10.31181/jscda41202678>
- [29] Vasantha Lakshmi, K., & Udaya Kumara, K. N. (2024). Fuzzy MCDM techniques for portfolio selection in the post-COVID Indian mutual fund industry. *Journal of Ambient Intelligence and Humanized Computing*, 16(1), 97-107. <https://doi.org/10.1007/s12652-024-04886-9>
- [30] Keshavarz-Ghorabae, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2021). Determination of objective weights using a new method based on removal effects of criteria. *Symmetry*, 13(4), 525. <https://doi.org/10.3390/sym13040525>
- [31] Ecer, F., & Pamucar, D. (2022). A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology. *Omega*, 112, 102690. <https://doi.org/10.1016/j.omega.2022.102690>
- [32] Güneri, B., Gökbayrak, O., & Duymaz, Ş. (2025). A fuzzy multi-criteria decision-making model based on F-entropy and F-ARAS. *Journal of Expert Systems and Sustainable Development*, 1(1), 38-57. <https://doi.org/10.65069/jessd1120254>
- [33] Więckowski, J., Kołodziejczyk, J. & Sałabun, W. (2025). Assessing the impact of criteria removal on Multi-Criteria Decision-Making stability: A simulation-based sensitivity analysis. In I. Luković, S. Bjeladinović, B. Delibašić, D. Barać, N. Iivari, E. Insfran, M. Lang, H. Linger, & C. Schneider (Eds.), *Empowering the Interdisciplinary Role of ISD in Addressing Contemporary Issues in Digital Transformation: How Data Science and Generative AI Contributes to ISD (ISD2025 Proceedings)*. Belgrade, Serbia. <https://doi.org/10.62036/ISD.2025.34>
- [34] Diakoulaki, M., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The CRITIC method. *Computers & Operations Research*, 22(7), 763-770. [https://doi.org/10.1016/0305-0548\(94\)00059-H](https://doi.org/10.1016/0305-0548(94)00059-H)
- [35] Yavaş Sezer, E. N. (2025). Money market funds in Turkey. In: Ustaoglu, M., Çakmak, C. (eds) *The Palgrave Encyclopedia of Islamic Finance and Economics*. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-93703-4_433-1
- [36] Macit, Ş. N. (2026). An integrated MCDM framework for sensitivity of weighting methods and ranking outcomes. *Decision Making Advances*, 4(1), 303-336. <https://doi.org/10.31181/dma412026196>
- [37] Yildirim, R., Oner, M. H., & Tekdoğan, Ö. F. (2026). From depth to dynamics: Sukuk market development and capital buffer adjustment in Islamic banks. *International Journal of Islamic and Middle Eastern Finance and Management*, 1-28. <https://doi.org/10.1108/imefm-12-2025-0968>
- [38] Kocaman, M. (2026). Does the growth relevance of Islamic bank financing vary across growth regimes? *International Journal of Islamic and Middle Eastern Finance and Management*, 1-28. <https://doi.org/10.1108/imefm-01-2026-0058>
- [39] Zakaria, N. B., Musa, K., Kabir, M. R., & Sobhani, F. A. (2024). The impact of geopolitical risk and COVID-19 pandemic stringency on sukuk markets. *Journal of Islamic Accounting and Business Research*, 17(7), 1308-1323. <https://doi.org/10.1108/jiabr-06-2023-0190>
- [40] Hakim, A., & Baqir, R. (2025). Sovereign sukuk in default. *Journal of International Economic Law*, 28(3), 382-403. <https://doi.org/10.1093/jiel/jgaf036>