

# Market-based financial literacy under macro-financial and political risk conditions: A rolling ARX–PCA proxy index for the BIST 100

*Makro-finansal ve politik risk koşulları altında piyasa temelli finansal okuryazarlık: BİST 100 için kayan ARX–PCA vekil endeksi*

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## Abstract

This study develops a time-varying Market-Based Financial Literacy Proxy Index (MBFLPI) for Borsa İstanbul's BIST 100 index. The term financial literacy is retained in a restricted sense: MBFLPI is an indirect, outcome-based market proxy, not a direct score of investors' knowledge, skills, attitudes or behaviour. Using actual BIST sessions from 1 August 2013 to 30 January 2026, a 252-session rolling ARX relates USD-denominated returns to Türkiye's two-year government bond yield, conservatively lagged industrial production, the five-year sovereign CDS, and the VIX. It derives benchmark macro-financial alignment, low first-order return predictability and model-based residual stability; rolling PCA combines the diagnostics, and the composite is rescaled to 0–100 for ex post presentation. Sensitivity analysis varies the window, aggregation, calibration, return denomination and normalisation. Event movements are descriptive associations, not evidence of causal transmission. Published Türkiye evidence provides an external benchmark: pre-sample S&P and OECD/INFE–Capital Markets Board reports supply historical context, whereas fieldwork-matched TEB–Boğaziçi University and FODER–Visa Türkiye/Ipsos surveys and monthly Capital Markets Board investor statistics yield mixed or null evidence. The comparison does not support convergent validity. MBFLPI therefore remains a complementary market-level proxy rather than a substitute for survey-based financial literacy.

**Keywords:** Financial literacy, market-based proxy index, BIST 100, return predictability

## Öz

Bu çalışma, Borsa İstanbul (BIST) 100 için zamanla değişen bir Piyasa Temelli Finansal Okuryazarlık Vekil Endeksi (MBFLPI) geliştirmektedir. Finansal okuryazarlık ifadesi dar anlamda korunmuştur: MBFLPI, yatırımcıların bilgi, beceri, tutum veya davranışlarını doğrudan ölçen bir puan değil, piyasa sonuçlarına dayalı dolaylı bir vekildir. 1 Ağustos 2013–30 Ocak 2026 arasındaki fiili BIST seansları kullanılarak 252 seanslık kayan ARX modelinde dolar bazlı getiriler, iki yıllık tahvil faizi, ihtiyatlı biçimde geciktirilmiş sanayi üretimi, beş yıllık ülke CDS primi ve VIX ile ilişkilendirilmektedir. Modelden ölçüt makro-finansal uyum, düşük birinci dereceden getiri öngörülebilirliği ve model-temelli artık istikrarı tanıları türetilmekte; kayan PCA ile birleştirilen bileşik gösterge, sunum amacıyla 0–100 aralığına dönüştürülmektedir. Duyarlılık analizi pencereyi, toplulaştırmayı, kalibrasyonu, getiri para birimini ve normalleştirmeyi değiştirmektedir; olay hareketleri nedensel değil betimseldir. Türkiye için yayımlanmış kanıtlarla yapılan dış ölçüt karşılaştırmasında, örneklem öncesi S&P ve OECD/INFE–Sermaye Piyasası Kurulu raporları tarihsel bağlam sağlarken, saha dönemiyle eşleştirilen TEB–Boğaziçi Üniversitesi ve FODER–Visa Türkiye/Ipsos anketleri ile aylık Sermaye Piyasası Kurulu yatırımcı istatistikleri karma veya ilişkisiz sonuçlar vermektedir. Karşılaştırma yakınsak geçerliliği desteklememektedir. MBFLPI anket-temelli finansal okuryazarlığın yerine geçmeyen, tamamlayıcı bir piyasa düzeyi vekili olarak kalmaktadır.

**Anahtar Kelimeler:** Finansal okuryazarlık, piyasa temelli vekil endeks, BIST 100, getiri öngörülebilirliği

## Introduction

Economic literacy is a broad concept that denotes the rationality of economic decision-making entities in addressing economic issues. In the contemporary global economic and financial framework, which operates around the clock, financial literacy is undeniably one of the most crucial elements of economic literacy. To fully comprehend the multifaceted nature of financial literacy, it must be defined qualitatively in a broad context and quantitatively in a specific one. Financial literacy broadly denotes the ability of economic and financial agents to rationally assess financially relevant events. Financial literacy, in a more specific context, refers to an individual's capacity to make informed decisions concerning expenditure, consumption, savings, investments, and financing. Financial literacy can also be defined as an individual's ability to make informed decisions by understanding financial products, risks, rights, and opportunities. In this context, a comprehensive analysis of financial literacy requires the systematic differentiation and elucidation of its components (Lusardi & Mitchell, 2014; OECD, 2020; Remund, 2010) (see Figure 1: A).

The subdimensions of financial literacy constitute a complex, interconnected framework for the phase transitions of financial phenomena and entities, grounded in scientific rigour. Consequently, examining this complex structure from the inside out facilitates a more precise understanding of financial literacy.

The fundamental element of financial literacy is the notion of financial data. Financial data is the collection of quantitative metrics related to financial assets and liabilities within financial markets. In contrast, financial information refers to significant datasets of financial data. The financial knowledge component encompasses the capacity to identify quantitative factors, including interest rates, inflation, compound returns, time value of money, risk-return relationship, liquidity, maturity, diversification, real returns, budget balance, debt cost, and investment instruments. From the standpoint of the financial knowledge framework, financial literacy is

intricately linked to maximising returns through the logical assessment of financially relevant information.

A significant aspect is the behavioural finance component. Behavioural finance concerns the influence of internal and external psychological factors on the financial decisions of decision-making entities when assessing risk, return, and cost. An individual's behavioural finance profile influences the decision-making process within financial decision matrices. This effect correlates with the financial mindset factor. Financial attitude refers to the cognitive abilities and inclinations necessary for effectively navigating financial decision-making processes, including saving, investing, spending, consuming, borrowing, and producing. The implementation of a systematic and coherent financial approach by financial decision-making entities directly enhances financial awareness. Financial awareness is the capacity to understand financial phenomena and entities logically.

The accurate fulfilment of the subdimensions of financial literacy allows a financial decision made at a certain instant,  $t_0$ , to have implications in the medium and long term, such as at  $t_1$ ,  $t_2$ , and  $t_n$ . The dimension of financial strategic meta-knowledge refers to the ability of financial decision-making units to systematically and progressively enhance their technical financial literacy from short-, medium-, and long-term perspectives in a manner that optimises returns. Consequently, financial literacy is intricately linked to risk management and long-term financial strategy. To effectively analyse this relationship, it is essential to identify and compute financial decision-making criteria, including the risk premium, discount factor, cost of capital, profitability, and internal rate of return, in the most suitable method.

Consequently, in light of the digitised global and local political-economic landscape of the present era, the significance of digital literacy has escalated as a technical extension of financial literacy. The proliferation of digital literacy into digital financial literacy, facilitated by fintech instruments, increases complexity in financial markets at the mi-

cro, meso, and macro levels, significantly complicating rational financial decision-making. This problematic position leads to varying levels of financial literacy among countries, resulting in asymmetrical and unreasonable long-term returns at the micro, meso, and macro levels.

The enduring nature of financial literacy directly influences individuals' welfare and helps maintain and enhance their wealth, ensuring its value remains intact over time. In economies characterised by high levels of financial literacy, savings rates are anticipated to rise, capital markets are projected to expand, the banking system is expected to function more robustly and with reduced stress, resource allocation is likely to become more efficient, and resilience to economic crises is expected to increase. Consequently, financial literacy is a crucial economic competency that enhances individual quality of life and promotes macroeconomic sustainability in contemporary countries.

In countries characterised by low financial literacy, the risk premium typically escalates; hence, illicit activities such as fraud, money laundering, and market monopolisation may yield greater asymmetric, predominantly unlawful rewards due to the heightened premium. In countries with a significant risk premium within a risk-return linearity framework, economic actors can exploit this premium to achieve disproportionately higher unlawful returns.

Given the impact of financial literacy at the micro, meso, and macro levels, its determinants must be examined systematically. In this context, the primary practical measures of financial literacy include budget management and savings awareness at both individual and institutional levels. Budget management concerns the precise prediction of income and expenditures, whereas saving awareness concerns the optimal proportion of income to set aside as savings. The notion of investment literacy is crucial for effective budget management and saving practices.

At this level, a crucial subindicator of financial literacy is investment literacy. Investment literacy constitutes a subcategory of financial literacy. It pertains to individuals' capacity to manage their

assets by considering quantitative metrics such as risk-return and cost-benefit analyses, rather than depending on story economics for their investment choices. The element that directly influences investment literacy is the financial education component. Financial education refers to instructional activities designed to empower economic decision-making entities to understand financial markets and utilise financial tools judiciously.

In this perspective, the sole demographic element influencing financial literacy is not the educational attainment of financial decision-making units. Various social and demographic characteristics, including income, age, gender, occupation, family structure, cultural context, geographical location, and access to technology, determine the degree of financial literacy. The demographic aspect of financial literacy highlights the interconnected ideas of financial democratisation and inclusion. The democratisation of finance refers to the horizontal expansion of financial services beyond affluent demographics to encompass wider social groups. In contrast, financial inclusion denotes the capacity for effective, timely access to financial services on a vertical scale.

This study, in accordance with the conceptual and theoretical framework, does not regard financial literacy solely as an issue of individual financial knowledge. It defines financial literacy as a quantifiable market capability that indicates the degree to which the capital market can rationally, consistently, and without anomalies integrate macro-financial and political information into pricing. A market-oriented macro-financial and political literacy index is created for the BIST 100. The empirical framework of the index relies on the dynamic pricing response of USD-denominated BIST 100 returns to interest rates, industrial production, the country risk premium, and global risk perception. The country's risk premium includes the political risk premium within this framework.

Financial literacy is also conventionally an individual-level construct concerning financial knowledge, skills, attitudes and behaviours (Atkinson and Messy, 2012; Lusardi and Mitchell, 2014; OECD, 2022, 2023a, 2026). Aggregate equity-

price data contains none of those direct measurements. Figure 1, therefore, distinguishes conventional financial-literacy measurement from the indirect, market-based proxy examined in this study.

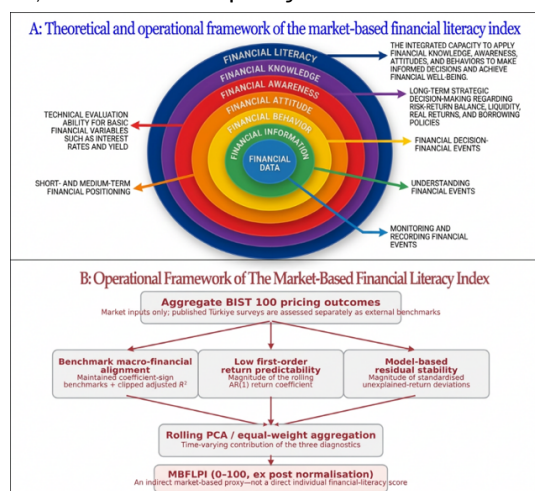


**Figure 1. Theoretical and operational framework of the market-based financial literacy index**

Source. Prepared by the authors.

The empirical object examined here is the aggregate BIST 100 return-generating process. It is defined by three observable diagnostics: conformity with maintained macro-financial coefficient-sign benchmarks and model fit; first-order dependence on past returns; and the magnitude of standardised deviations left unexplained by the selected model. These diagnostics concern pricing outcomes; they are not attributes of a particular investor or investor group.

The financial-literacy label is therefore retained only with an explicit qualification. Neither a rolling coefficient nor a regression residual reveals investors' knowledge, competence or psychological state. The Market-Based Financial Literacy Proxy Index (MBFLPI) instead represents a possible market-level manifestation of selected macro-financial information-processing outcomes. It must not be interpreted as a direct investor-level literacy measure.

The study asks whether selected time-varying features of aggregate pricing can be combined in a transparent monitoring indicator and whether the resulting series remains similar under reasonable design alternatives. The maintained coefficient signs are treated as analytical benchmarks rather

than universal laws; the AR(1) term is treated as a narrow return-predictability diagnostic; and residual size is treated as a measure of unexplained variation rather than panic, herding or irrationality.

Empirically, the analysis reconstructs the sample from observed BIST trading sessions, applies conservative availability rules to daily and monthly covariates, estimates rolling ARX models, and combines the three diagnostics via rolling PCA. The baseline uses a 252-session window and USD-denominated returns. Robustness checks use 126- and 504-session windows, equal weights, alternative internal weights and thresholds, nominal-TL and HICP-deflated TL returns, and recursive rather than full-sample normalisation.

The principal contribution is methodological. The rolling ARX–PCA architecture allows the contribution of the three pricing diagnostics to vary over time and supplies an auditable sensitivity framework. It offers a reproducible, complementary market-based proxy for financial literacy while preserving the distinction between aggregate pricing outcomes and directly measured individual financial literacy.

All interpretations are explicitly model-dependent. Contemporaneous market variables may adjust jointly to common news; coefficient signs can change across monetary-policy and inflation regimes; Türkiye's five-year CDS spread is a sovereign-risk proxy rather than a pure political-risk measure; and contextual event markers do not identify causal effects. These boundaries motivate the revised scope, method and limitations below.

## Literature Review

Because the empirical indicator is constructed from aggregate market outcomes, the literature review distinguishes conventional individual-level financial-literacy measures from market-level pricing diagnostics. The first body of research clarifies how financial literacy is measured and why aggregate returns cannot provide a direct individual score. The second provides the methodological

basis for conditional price responses, return predictability, unexplained return variation and composite-indicator construction.

### ***Individual Financial Literacy and Market Participation as Adjacent Constructs***

The financial literacy literature originally focused on individuals' ability to understand fundamental financial concepts, evaluate financial products, and make sound personal financial decisions. Huston (2010) highlighted conceptual uncertainty in measuring financial literacy and argued that it should not be viewed solely as a series of financial knowledge assessments. Remund (2010) suggested that financial literacy should be regarded as a multifaceted construct encompassing knowledge, skills, confidence, motivation, and the ability to make financial decisions. Lusardi and Mitchell (2014) defined financial literacy as an element of human capital that influences individuals' lifelong financial decision-making, and they established that financial knowledge is a crucial factor in saving, retirement planning, investment choices, and overall welfare. This methodology achieved institutional recognition through the multidimensional framework introduced by Atkinson and Messy (2012) within the OECD/INFE context, which assesses financial literacy across the elements of financial knowledge, financial behaviour, and financial attitude. Consequently, in the financial literacy literature, the measurement issue has evolved into both a technical concern about scale development and a critical research domain addressing financial decision quality, financial well-being, and market participation (Atkinson & Messy, 2012; Huston, 2010; Lusardi & Mitchell, 2014; Remund, 2010).

The OECD/INFE framework has been central to the development of internationally comparable financial literacy measurement. For Türkiye, the 2014 S&P Global Financial Literacy Survey classified 24 per cent of adults as financially literate under its four-concept rule (Klapper, Lusardi and van Oudheusden, 2015). The G20/OECD-INFE exercise, commissioned by the Capital Markets Board and fielded in May–June 2015, reported 4.6/7 for

knowledge, 4.8/9 for behaviour, 3.1/5 for attitudes, and 12.5/21 overall (OECD, 2017). These independent cross-sectional measures define the individual-level domain but predate the valid MBFLPI composite and cannot validate its temporal movements.

Research examining the empirical effects of financial literacy has convincingly shown its influence on individual financial behaviour. Lusardi and Mitchell (2011a) demonstrated, using U.S. data, that individuals with higher financial literacy are more likely to engage in retirement planning. The same authors' international comparative analysis demonstrated that financial illiteracy is not just an issue in developing economies but also prevalent in developed nations (Lusardi & Mitchell, 2011b). Klapper, Lusardi, and van Oudheusden (2015), in the context of the S&P Global Financial Literacy Survey, analysed financial literacy levels across 148 countries and demonstrated that insufficient financial knowledge is a worldwide barrier to financial inclusion. Kadoya and Khan (2020) examined financial literacy in Japan by assessing the dimensions of financial knowledge, attitudes, and behaviour, revealing that socio-demographic factors substantially influence financial literacy. Klapper, Lusardi, and Panos (2013) demonstrated that, in the context of the Russian financial crisis, financial literacy significantly influences individuals' borrowing and financial decision-making behaviours.

A significant area of financial literacy literature examines individuals' engagement in capital markets. Guiso and Jappelli (2005) argued that insufficient awareness of financial assets increases the costs associated with stock market participation, which is significant for elucidating the stockholding puzzle. van Rooij, Lusardi, and Alessie (2011) demonstrated, using Dutch household data, that individuals with lower financial literacy are markedly less inclined to invest in the stock market. In a similar vein, van Rooij, Lusardi, and Alessie (2012) found that financial literacy correlates with retirement planning and household wealth. Campbell (2006) highlighted in the household finance literature that people's ability to utilise financial markets

influences welfare outcomes; yet certain individuals exhibit a heightened propensity to misinterpret financial products and make financial errors. These studies demonstrate that financial literacy is not solely a function of knowledge but is also critical for market participation, portfolio selection, and financial well-being.

The methodological aspect of measuring financial literacy has evolved through scale development, psychometric modelling, and other indexing methods. Knoll and Houts (2012) developed a financial knowledge scale using Item Response Theory, providing an advanced psychometric framework that accounts for item difficulty and individual competence levels in assessing financial literacy. Potrich, Vieira, and Kirch (2015) investigated financial literacy by assessing the components of financial attitudes, financial behaviour, and financial knowledge, and by exploring its demographic and socioeconomic antecedents. Warmath and Zimmerman (2019) contended that financial literacy encompasses more than just information; it must also be assessed alongside skills, self-efficacy, and the ability to apply knowledge in practice. Bongini et al. (2018) demonstrated that measurement methods can influence findings by comparing OECD/INFE-based financial literacy measures in the Italian context using various data analysis techniques. Rieger (2020) demonstrated that many financial literacy metrics may exhibit weak interrelations and that the selection of measurement can influence empirical outcomes. The meta-analysis by Fernandes, Lynch, and Netemeyer (2014) revealed that the behavioural impacts of financial education interventions may be constrained; thus, financial literacy should be approached not solely through educational initiatives, but also in conjunction with behavioural and institutional frameworks.

Studies conducted in Türkiye and in the international literature define financial literacy at the individual level. The TEB–Boğaziçi University Financial Literacy and Access Index reports measure financial knowledge, attitudes and behaviour in repeated national samples; the 2016–2020 waves with disclosed fieldwork windows are therefore

the closest published benchmarks available within the MBFLPI period (TEB and Boğaziçi University, 2016–2022). Sarıgül (2015), Akben-Selçuk and Altıok-Yılmaz (2014), Knoll and Houts (2012), Potrich, Vieira and Kirch (2015), and Warmath and Zimmerman (2019) likewise use individual observations. Market participation is adjacent to, but not equivalent to, literacy, because wealth, access, costs, incentives, and risk tolerance also affect participation (Guiso and Jappelli, 2005; van Rooij, Lusardi, and Alessie, 2011).

### **Composite Indicators and Market-Based Pricing Diagnostics**

Composite-indicator research supports the transparent combination of several observable dimensions without assigning them an unsupported common substantive meaning. Nardo et al. (2005) and OECD/European Union/EC-JRC (2008) emphasise an explicit theoretical framework, transparent variable selection and transformation, defensible weighting and normalisation, and sensitivity analysis. Jolliffe (2002), Jolliffe and Cadima (2016), and Chao and Wu (2017) show how PCA can summarise common variation and provide data-driven weights. These sources support the aggregation method; they do not determine that the result measures literacy, efficiency or rationality.

The market-efficiency literature provides a separate basis for examining return dependence. Fama (1970) relates informational efficiency to the incorporation of available information into prices, while Lo and MacKinlay (1988) show that return dependence and departures from a random walk can be tested empirically. A single AR(1) coefficient, however, captures only first-order linear dependence. A small absolute coefficient is therefore used here as a narrow return-predictability diagnostic, not as conclusive evidence of market efficiency.

Behavioural finance research explains why sentiment, overreaction, and information cascades may influence prices (Kahneman and Tversky, 1979; De Bondt and Thaler, 1985; Bikhchandani, Hirshleifer and Welch, 1992; Barberis, Shleifer and Vishny, 1998; Shleifer, 2000). Yet an aggregate

ARX residual cannot identify those mechanisms. It may also reflect omitted news, sector-specific information, policy announcements, structural breaks, changing volatility, non-linearity or misspecification. The residual-based component is therefore interpreted only as model-based residual stability.

The research gap is the absence of a transparent, time-varying market-based financial-literacy proxy that jointly summarises conditional macro-financial alignment, first-order return predictability and model-based residual stability for the BIST 100. The study addresses this gap by integrating rolling ARX estimation, rolling PCA aggregation, a pre-specified sensitivity analysis and an explicit comparison with published Türkiye-specific external benchmarks, while preserving the boundary between market outcomes and investor-level characteristics and reporting discordant evidence rather than assuming validation.

### **Research Scope, Operational Definition, Original Contribution and Limits of Inference**

The model dataset contains no investor survey, financial knowledge test, investor identifier, investor composition series, retail participation measure, or transaction-level classification. It cannot determine individual literacy or distinguish retail investors from institutional or domestic investors. Published Türkiye surveys are not included in the ARX-PCA construction; they are used only in a separate post-estimation external-benchmark comparison. The expression "financial literacy" is therefore used only as an indirect, outcome-based market proxy rather than as the empirical identity of an individual-level construct.

Market-based financial literacy is operationally defined here as a possible aggregate manifestation of selected characteristics of the conditional BIST 100 return-generating process: (i) coefficient signs and model fit relative to stated macro-financial benchmarks; (ii) limited first-order dependence on past returns; and (iii) comparatively small standardised deviations from the selected ARX specification. This definition is model-dependent and

does not claim to observe a true fundamental price, to establish complete informational efficiency, or to evaluate participants' financial competence.

The benchmark macro-financial alignment diagnostic measures the extent to which rolling coefficients satisfy the maintained sign conditions for the interest rate, lagged industrial production, sovereign CDS, and VIX variables, as well as the clipped adjusted R-squared. These signs are reference points, not universal asset-pricing laws. A sign change may reflect a different information content, a monetary policy regime, common news effects, simultaneous adjustment, endogeneity, or model misspecification. Coefficients are thus interpreted as conditional co-movements rather than causal effects or proof of correct or incorrect pricing.

The low first-order return-predictability diagnostic is derived from the absolute AR(1) coefficient and captures only immediate linear serial dependence. It is not a comprehensive test of weak-form efficiency. The residual-stability diagnostic is derived from the magnitude of standardised ARX residuals. Large residuals indicate greater unexplained variation in returns under the model; they do not directly identify overreaction, herding, panic, speculation, optimism, or pessimism.

Rolling PCA combines the three diagnostics using time-varying PC1 weights. A higher MBFLPI value means that, relative to the selected model, transformations, thresholds and sample scaling, the return process shows greater benchmark sign alignment and fit, less AR(1)-type dependence and smaller standardised residual deviations. The 0–100 scale is a relative ex post normalisation, not a cardinal literacy score, a welfare measure, or a universal threshold.

The study's originality lies in integrating rolling ARX estimates and rolling PCA weights within an outcome-based financial-literacy proxy and then exposing that architecture to a defined sensitivity grid. The contribution is methodological and complementary: it retains financial literacy as the motivating concept without treating aggregate market prices as a direct measure of individual knowledge or competence.

The main limits follow directly from this scope. Contemporaneous financial variables may move together in response to common information; CDS is a broad sovereign-risk proxy rather than a pure political-risk measure; event markers are descriptive; USD returns embed exchange-rate movements; and results remain conditional on the variables, availability rules, window length, weights, thresholds, return denomination and normalisation. The sensitivity analysis evaluates these choices, while questions requiring investor-level, announcement-surprise or causal evidence remain outside the present design.

## Research Design, Data Set, and Methodology

### Research Design

This study constructs MBFLPI as an indirect, market-based proxy for financial literacy using selected aggregate pricing characteristics of the BIST 100. It does not directly measure the knowledge, skills, attitudes or behaviour of any investor group. The research design links an availability-aligned return equation to three model-based diagnostics, evaluates whether the resulting composite is stable under alternative design choices and compares it with independent, published financial-literacy benchmarks for Türkiye.

The empirical questions are: how do benchmark macro-financial alignment, first-order return predictability and residual stability vary over time; how do rolling PC1 weights distribute the contribution of those diagnostics; how sensitive is the composite to calendar treatment, window length, weighting, thresholds, currency denomination and normalisation; and do fieldwork-matched MBFLPI means move in the same direction as published Türkiye-specific financial-literacy survey scores? Figure 2 summarises the revised sequence.

The workflow first reconstructs the actual session and availability-aligned panel; next, it estimates conditional ARX relationships; then constructs M, E and Q; and finally compares rolling PC1

and alternative composite specifications. The design separates model diagnostics from investor-level interpretations.

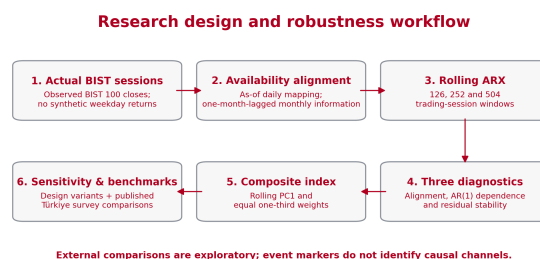


**Figure 2. Research design and robustness workflow.**

### Data Set, Source Metadata and Timing

The raw sample begins on 1 August 2013 and ends on 30 January 2026, the final observed BIST 100 session before 1 February 2026. The master calendar contains 3,133 dates with a non-missing raw BIST 100 close. Weekends, exchange holidays and other non-trading dates were not inserted, and the BIST 100 level was never carried forward. A return following a closure was calculated between consecutive observed BIST closes and therefore retains the cumulative movement across that closure.

The baseline dependent variable is the USD-denominated BIST 100 return. It provides a foreign-currency valuation perspective and embeds both equity-price and USD/TRY movements; it is not neutral across investor groups and cannot distinguish domestic from foreign or retail from institutional investors. Nominal-TL and HICP-deflated TL returns are consequently analysed as sensitivity variants rather than being treated as interchangeable measures.

The archived inputs comprise BIST 100, USD/TRY, Türkiye's two-year benchmark government bond yield, a supplied industrial production path, Türkiye's five-year sovereign CDS spread, and the VIX. Table 1 reports the archived filenames, raw headers, units, coverage and timing rules. Exact intraday vendor timestamps, official industrial-production release timestamps and first-release vintages were not retained in the archived files; these constraints are disclosed rather than imputed.

**Table 1. Source Series, Archived Metadata and Availability Rules**

| Series                    | Archived file / raw header                                               | Coverage and unit                                                   | Availability rule                                                                                | Model transformation                                                        |
|---------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| BIST 100 close            | BIST-100-Geçmiş-Verileri_4_(1).xlsx / Tarih, bist-100                    | 4 Jan 2010–4 May 2026; index points; 3,133 observed sample dates    | Master calendar; observed close only; never filled                                               | $100\Delta\ln(\text{BIST100})$ ; also $\text{BIST100/USDTRY}$ for USD level |
| USD/TRY                   | USD_TRY-Geçmiş-Verileri_3_(1).xlsx / Tarih, usd_tr                       | 1 Jan 2010–4 May 2026; TL per USD; archived scale divided by 10,000 | Most recent non-missing value dated on or before BIST session; intraday timestamp unavailable    | USD return through $\text{BIST100/USDTRY}$                                  |
| Two-year yield            | 2 YEAR BOND(2).xlsx / Tarih, reference_rate                              | 4 Jan 2010–1 May 2026; decimal yield                                | As of on or before the BIST session; exact quote time unavailable                                | First difference $\times 100$ , percentage points                           |
| Industrial production     | sanayi üretim(1).xlsx / _date_, mpi                                      | 1 Aug 2013–1 Feb 2026; supplied daily-expanded index path           | Calendar-month final snapshot; month $m-1$ used in month $m$ ; not exact release-vintage mapping | Log change in lagged monthly state; zero between updates                    |
| Türkiye five-year CDS     | CDS(1).xlsx / Tarih, CDS                                                 | 4 Jan 2010–1 May 2026; basis points                                 | As of on or before the BIST session, the sovereign-risk proxy                                    | $100\Delta\ln(\text{CDS})$                                                  |
| VIX                       | VIX(1).xlsx / Tarih, vix                                                 | 4 Jan 2010–4 May 2026; index points                                 | Most recent non-missing US close strictly before the BIST date                                   | $100\Delta\ln(\text{VIX})$ after timing alignment                           |
| Türkiye HICP (robustness) | Türkiye_Mudahasiz_Doviz_Kuru_Hesaplari_2013_2026.xlsx / tr_hicp_2025_100 | 2013–2026; index, 2025=100                                          | Monthly snapshot lagged one month; latest archived vintage                                       | $100\Delta\ln(\text{BIST100/HICP})$                                         |

**Source.** Investing.com (n.d.) for the BIST 100 close, USD/TRY, Türkiye's two-year benchmark government bond yield, Türkiye's five-year sovereign CDS spread and VIX series; Central Bank of the Republic of Türkiye (n.d.), Electronic Data Delivery System (EVDS), for industrial production and Türkiye HICP. Authors' calculations.

**Table 2. Transformation and Component-Construction Dictionary**

| Raw Variable / Source Series                     | Derived Time Series                     | Equation / Formula                                                                                                               | Index or Component Used                                        |
|--------------------------------------------------|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| BIST100_Close                                    | BIST_USD                                | $\text{BISTUSD}_t = \text{BIST100}_t / \text{USDTRY}_t$                                                                          | Main market reference series                                   |
| BIST100_Close, USDTRY                            | bist_100_usd_return                     | $r^{\text{USD}}_t = 100 \times \Delta\ln(\text{BISTUSD}_t)$                                                                      | Rolling ARX model; core dependent variable for all sub-indices |
| bist_100_usd_return                              | Lagged_BIST_USD_Return                  | $r^{\text{USD}}_{t-1}$                                                                                                           | Low first-order return-predictability diagnostic               |
| Reference_Rate_2Y                                | Rate_Change                             | $\Delta i_t = i_t - i_{t-1}$                                                                                                     | Benchmark Macro-Financial Alignment Diagnostic                 |
| Industrial_Production                            | Industrial_Production_Growth            | $G^{\text{IP}}_t = 100[\ln(\text{IP}^{\text{m}}_{t-1}) - \ln(\text{IP}^{\text{m}}_{t-2})]$ , $t$ in month $m$                    | Benchmark Macro-Financial Alignment Diagnostic                 |
| CDS_5Y                                           | CDS_Change                              | $\Delta\ln(\text{CDS}_t) = 100 \times [\ln(\text{CDS}_t) - \ln(\text{CDS}_{t-1})]$                                               | Benchmark Macro-Financial Alignment Diagnostic                 |
| VIX                                              | VIX_Change                              | $\Delta\ln(\text{VIX}_t) = 100 \times [\ln(\text{VIX}_t) - \ln(\text{VIX}_{t-1})]$                                               | Benchmark Macro-Financial Alignment Diagnostic                 |
| ARX inputs                                       | Rolling ARX Coefficients                | Equation (6)<br>$+ \beta_{3,t}\Delta\ln(\text{CDS}_t) + \beta_{4,t}\Delta\ln(\text{VIX}_t) + \varepsilon_t$                      | Rolling coefficients and fit                                   |
| Rolling ARX Coefficients                         | Sign concordance / $\text{MU}_t$        | $\text{MU}_t = [I(\beta_{1,t} < 0) + I(\beta_{2,t} > 0) + I(\beta_{3,t} < 0) + I(\beta_{4,t} < 0)] / 4$                          | M diagnostic                                                   |
| Rolling ARX Model                                | Clipped adjusted $R^2$ / $\text{MA}_t$  | $\text{MA}_t = \max\{0, \min(\text{Adj. } R^2_t, 1)\}$                                                                           | M diagnostic                                                   |
| $\text{MU}_t, \text{MA}_t$                       | Benchmark alignment / $\text{M}_t$      | $\text{M}_t = 0.60 \text{MU}_t + 0.40 \text{MA}_t$                                                                               | First diagnostic                                               |
| bist_100_usd_return                              | AR coefficient / $\phi_t$               | $\phi_t = \text{AR}(1)(r^{\text{USD}}_t)$                                                                                        | E diagnostic                                                   |
| $\phi_t$                                         | Low AR(1) predictability / $\text{E}_t$ | $\text{E}_t = 1 - \min( \phi_t /0.50, 1)$                                                                                        | Second diagnostic                                              |
| Rolling ARX Model                                | One-step-ahead fitted return            | Equation (6), fitted                                                                                                             | Residual diagnostic                                            |
| Observed and fitted return                       | One-step-ahead residual                 | $\varepsilon_t = r^{\text{USD}}_t - \hat{r}^{\text{USD}}_t$                                                                      | Residual diagnostic                                            |
| Model_Residual_Epsilon                           | Rolling residual scale                  | $\sigma_{\text{err}} = \sqrt{(\sum_t \varepsilon_t^2) / (n - k)}$                                                                | Residual diagnostic                                            |
| Residual and residual scale                      | Standardised residual / $z_t$           | $z_t = \varepsilon_t / \sigma_{\text{err}}$                                                                                      | Residual diagnostic                                            |
| Standardised residual / $z_t$                    | Residual deviation / $\text{D}_t$       | $\text{D}_t = \min( z_t /3, 1)$                                                                                                  | Inverse used for $\text{Q}_t$                                  |
| Residual deviation / $\text{D}_t$                | Residual stability / $\text{Q}_t$       | $\text{Q}_t = 1 - \text{D}_t$                                                                                                    | Third diagnostic                                               |
| $\text{M}_t, \text{E}_t$ and $\text{Q}_t$        | Rolling PC1 loadings                    | PC1 on preceding 252 valid triplets                                                                                              | Rolling PC1 weighting                                          |
| PC1 Loadings                                     | $w_M$                                   | $w_{\{M,t\}} = v^2_{\{M,t\}} / \sum_{j \in \{M,E,Q\}} v^2_{\{j,t\}}$                                                             | M weight                                                       |
| PC1 Loadings                                     | $w_E$                                   | $w_{\{E,t\}} = v^2_{\{E,t\}} / \sum_{j \in \{M,E,Q\}} v^2_{\{j,t\}}$                                                             | E weight                                                       |
| PC1 Loadings                                     | $w_Q$                                   | $w_{\{Q,t\}} = v^2_{\{Q,t\}} / \sum_{j \in \{M,E,Q\}} v^2_{\{j,t\}}$                                                             | Q weight                                                       |
| $\text{M}_t, \text{E}_t, \text{Q}_t$ and weights | Raw MBFLPI                              | $\text{PC1\_raw}_t = w_{\{M,t\}}\text{M}_t + w_{\{E,t\}}\text{E}_t + w_{\{Q,t\}}\text{Q}_t$                                      | Raw composite                                                  |
| PC1_index_raw                                    | MBFLPI / PC1_index                      | $\text{PC1\_index}_t = 100 \times (\text{PC1\_raw}_t - \min(\text{PC1\_raw})) / [\max(\text{PC1\_raw}) - \min(\text{PC1\_raw})]$ | Ex post 0–100 composite                                        |

**Table 3. Descriptive Statistics for the Availability-Aligned Series and Revised Index**

| Series                                        | N    | Mean     | Median   | SD       | Minimum | Maximum   |
|-----------------------------------------------|------|----------|----------|----------|---------|-----------|
| BIST 100 close (index points)                 | 2609 | 3552.702 | 1291.290 | 3682.002 | 685.680 | 13838.290 |
| USD/TRY information state                     | 2609 | 14.451   | 7.473    | 12.824   | 2.795   | 43.492    |
| BIST 100 / USD/TRY level                      | 2609 | 227.526  | 240.315  | 55.289   | 126.997 | 339.510   |
| Türkiye HICP information state (2025=100)     | 2609 | 372.783  | 183.130  | 344.182  | 99.676  | 1167.845  |
| HICP-deflated BIST 100 level                  | 2609 | 8.441    | 7.874    | 2.067    | 4.917   | 15.312    |
| Two-year yield information state (decimal)    | 2609 | 0.199    | 0.157    | 0.107    | 0.080   | 0.459     |
| Lagged monthly industrial production state    | 2609 | 93.390   | 93.831   | 12.837   | 59.672  | 112.176   |
| Türkiye five-year CDS information state (bp)  | 2609 | 361.181  | 310.470  | 146.321  | 155.200 | 906.000   |
| Lagged VIX information state                  | 2609 | 18.440   | 16.660   | 7.209    | 9.140   | 82.690    |
| USD-denominated BIST 100 return (%)           | 2609 | 0.010    | 0.042    | 2.057    | -18.069 | 18.147    |
| Two-year yield change (pp)                    | 2609 | 0.008    | 0.000    | 0.477    | -6.890  | 5.640     |
| Lagged industrial-production state change (%) | 2609 | 0.014    | 0.000    | 0.946    | -33.153 | 14.668    |
| CDS log change (%)                            | 2609 | -0.009   | -0.007   | 3.069    | -24.964 | 39.950    |
| Lagged VIX log change (%)                     | 2609 | -0.016   | -0.464   | 7.904    | -44.245 | 76.825    |
| Rolling adjusted R <sup>2</sup>               | 2609 | 0.314    | 0.354    | 0.151    | 0.010   | 0.553     |
| Benchmark sign concordance (MU)               | 2609 | 0.783    | 0.750    | 0.164    | 0.500   | 1.000     |
| Benchmark macro-financial alignment (M)       | 2609 | 0.596    | 0.607    | 0.098    | 0.326   | 0.792     |
| Low first-order return predictability (E)     | 2609 | 0.787    | 0.855    | 0.189    | 0.000   | 1.000     |
| Standardised unexplained-return deviation (D) | 2609 | 0.254    | 0.199    | 0.214    | <0.001  | 1.000     |
| Model-based residual stability (Q)            | 2609 | 0.746    | 0.801    | 0.214    | 0.000   | 1.000     |
| Raw MBFLPI composite                          | 2609 | 0.703    | 0.715    | 0.106    | 0.243   | 0.964     |
| MBFLPI (0–100)                                | 2609 | 63.804   | 65.455   | 14.671   | 0.000   | 100.000   |

Table 3 reports descriptive statistics after the calendar and availability revisions. Level variables are shown to document scale and coverage; the ARX model uses returns, percentage-point changes and log changes. The index diagnostics and final composite are reported on their operative 0–1 or 0–100 scales. Descriptive moments characterise the sample but do not establish a threshold for high or low market quality.

The transformed market series are centred much closer to zero than their levels, as expected for daily changes. The industrial-production regressor updates only when the conservatively lagged monthly state changes; it must therefore be read as a sparse information-state variable rather than daily production growth. The residual and composite distributions are conditional on the revised ARX specification and cannot be translated into investor psychology or literacy.

MBFLPI is a relative sample index. Its mean, dispersion and extrema are used for comparisons within the present design, not as externally validated performance bands. In particular, a score near 60 or 80 has no direct interpretation as a percentage of information-processing capacity, rationality or financial knowledge.

Augmented Dickey–Fuller diagnostics were recalculated after reconstructing the actual-session panel. Table 4 reports the test statistic, selected lag, and 5 per cent decision for the level- or operative-transformed series used in the revised analysis. These tests are reported as time-series diagnostics; they do not validate the substantive interpretation of the composite.

Returns and daily changes are evaluated using the ARX equation. For bounded diagnostics and the normalised composite, ADF results should be interpreted with caution because mechanical

**Table 4. Augmented Dickey–Fuller Diagnostics for the Revised Analysis**

| Series                                        | Form             | Effective N | BIC lag | ADF t   | 5% decision          |
|-----------------------------------------------|------------------|-------------|---------|---------|----------------------|
| BIST 100 close (index points)                 | Operative level  | 2,582       | 26      | 2.061   | Do not reject        |
| BIST 100 close (index points)                 | First difference | 2,580       | 27      | -7.793  | Reject the unit root |
| USD/TRY information state                     | Operative level  | 2,607       | 1       | 3.691   | Do not reject        |
| BIST 100 / USD/TRY level                      | Operative level  | 2,608       | 0       | -1.729  | Do not reject        |
| Two-year yield information state (decimal)    | Operative level  | 2,606       | 2       | -1.211  | Do not reject        |
| Lagged monthly industrial production state    | Operative level  | 2,608       | 0       | -1.600  | Do not reject        |
| Türkiye five-year CDS information state (bp)  | Operative level  | 2,602       | 6       | -2.049  | Do not reject        |
| Lagged VIX information state                  | Operative level  | 2,607       | 1       | -5.878  | Reject the unit root |
| USD-denominated BIST 100 return (%)           | Operative level  | 2,608       | 0       | -50.956 | Reject the unit root |
| Two-year yield change (pp)                    | Operative level  | 2,607       | 1       | -31.514 | Reject the unit root |
| Lagged industrial-production state change (%) | Operative level  | 2,587       | 21      | -11.602 | Reject the unit root |
| CDS log change (%)                            | Operative level  | 2,608       | 0       | -48.184 | Reject the unit root |
| Lagged VIX log change (%)                     | Operative level  | 2,608       | 0       | -55.136 | Reject the unit root |
| Benchmark macro-financial alignment (M)       | Operative level  | 2,606       | 2       | -4.627  | Reject the unit root |
| Low first-order return predictability (E)     | Operative level  | 2,603       | 5       | -1.987  | Do not reject        |
| Model-based residual stability (Q)            | Operative level  | 2,605       | 3       | -19.045 | Reject the unit root |
| MBFLPI (0–100)                                | Operative level  | 2,599       | 9       | -3.597  | Reject the unit root |

bounds, rolling estimation, and full-sample rescaling can affect persistence. The absence of a unit root is neither a test of market efficiency nor evidence that the component captures investor behaviour.

The revised empirical interpretation, therefore, rests on the transparent construction and sensitivity results rather than on stationarity alone. Full ADF settings and the unrounded outputs are retained in the replication files.

## Research Method

The data dictionary, temporal-alignment protocol, transformation rules, parameter grid and replication sequence are reported in Appendices A–D. The equations below define the baseline specification; each researcher-imposed design choice is subsequently varied in the sensitivity analysis.

The baseline dependent variable is calculated as follows: nominal-TL and HICP-deflated TL alternatives use the same actual-session calendar:

Equation 1. USD-Denominated BIST 100 Return

$$r_t^{USD} = 100 \left[ \ln \left( \frac{BIST100_t}{USDTRY_t} \right) - \ln \left( \frac{BIST100_{t-1}}{USDTRY_{t-1}} \right) \right] \quad (1)$$

Here,  $r_t^{USD}$  is the log return of the BIST 100 expressed in US dollars,  $BIST100_t$  is the observed closing index value, and  $USDTRY_t$  is the eligible exchange-rate observation aligned to session  $t$ . The BIST 100 close is never forward-filled.

The availability-aligned explanatory variables are transformed as follows:

Equations 2–5. Explanatory-Variable Transformations

$$\Delta i_t = i_t - i_{t-1} \quad (2)$$

$$G_t^p = 100[\ln(IP_{m-1}^-) - \ln(IP_{m-2}^-)] \text{ for every BIST session } t \text{ in calendar month } m. \quad (3)$$

$$\Delta \ln(CDS_t) = 100[\ln(CDS_t) - \ln(CDS_{t-1})] \quad (4)$$

$$\Delta \ln(VIX_t) = 100[\ln(VIX_t) - \ln(VIX_{t-1})] \quad (5)$$

Here,  $\Delta i_t$  is the change in the two-year yield in percentage points;  $G_t^p$  is the log change in the conservatively lagged monthly industrial-production state;  $\Delta \ln(CDS_t)$  is the log change in the sovereign CDS spread; and  $\Delta \ln(VIX_t)$  is the change in the most recent US close available strictly before the BIST session.

## Data Pre-processing, Release Timing and Trading-Calendar Alignment

The master calendar contains only dates with an observed raw BIST 100 close. USD/TRY, the two-year yield and the five-year sovereign CDS spread were aligned to each BIST session by selecting the most recent non-missing observation dated on or before that session. Changes were calculated after alignment. This rule leaves the BIST return untouched, avoids synthetic zero-equity returns, and explicitly records when a covariate's information state has not changed.

Because the US market closes after Borsa İstanbul, the eligible VIX observation for BIST date  $t$  is the most recent non-missing US close dated strictly before  $t$ ; a same-date US close is never used. Industrial production is intrinsically monthly, but the archived file contains a smoothly expanded daily path without official release timestamps or real-time vintages. The revised construction takes each calendar month's final supplied snapshot and uses the month  $m-1$  snapshot throughout month  $m$ ; its log change, therefore, updates only on the first eligible BIST session of the month. This conservative lag prevents the daily interpolation from being treated as new information. Still, it is not an exact announcement date or a vintage alignment, and it does not support any claim of an announcement surprise.

## Rolling ARX Conditional Co-movement Model

The conditional co-movement equation is estimated recursively over  $W$  valid BIST sessions. For index date  $t$ , coefficients are estimated solely from the preceding  $W$  observations ending at  $t-1$ . The availability-aligned covariates at  $t$  are combined with those pre-estimated coefficients to obtain the date- $t$  conditional fitted return and one-step-ahead residual. The baseline uses  $W=252$ ;  $W=126$  and  $W=504$  are sensitivity alternatives. The realised date- $t$  return never enters its own coefficient estimates.

### Equation 6. Rolling ARX Pricing Equation

$$r_t^{USD} = \alpha_t + \phi_t r_{t-1}^{USD} + \beta_{1,t} \Delta i_t + \beta_{2,t} \Delta \ln(IPI_t) + \beta_{3,t} \Delta \ln(CDS_t) + \beta_{4,t} \Delta \ln(VIX_t) + \varepsilon_t \quad (6)$$

The maintained directional benchmarks are  $\beta_{rate,t} < 0$ ,  $\beta_{IP,t} > 0$ ,  $\beta_{CDS,t} < 0$  and  $\beta_{VIX,t} < 0$ . Equation (6) is a reduced-form conditional co-movement model, not a structural asset-pricing equation. Returns, yields, CDS, and global risk measures can respond jointly to common news, and a coefficient's information content can change across monetary policy, inflation, and risk regimes. The signs are transparent analytical benchmarks rather than universal restrictions; coefficients do not identify causal effects or prove that investors priced a variable correctly or incorrectly.

### Construction of the Three Pricing Diagnostics

The first diagnostic, benchmark macro-financial alignment, combines a benchmark sign-concordance score with clipped conditional explanatory fit. The sign score records how many rolling coefficients conform to the four stated directions; it does not classify market behaviour as rational or irrational.

### Equation 7. Benchmark Sign-Concordance Score

$$MU_t = \frac{I(\beta_{1,t} < 0) + I(\beta_{2,t} > 0) + I(\beta_{3,t} < 0) + I(\beta_{4,t} < 0)}{4} \quad (7)$$

$MU_t$  lies between zero and one and equals the share of the four maintained sign conditions satisfied in window  $t$ .  $I(\cdot)$  is an indicator function. Non-concordance means only that the conditional co-movement differs from the maintained benchmark.

### Equation 8. Clipped Conditional Explanatory-Fit Score

$$MA_t = \max\{0, \min(\text{Adjusted } R^2_t, 1)\}. \quad (8)$$

$MA_t$  is the rolling adjusted  $R^2$  bounded to  $[0,1]$ . The unbounded adjusted  $R^2$  is also retained in the rep-

lication output. Clipping prevents a negative adjusted  $R^2$  from creating a component outside its stated scale; it does not transform model fit into a measure of correct pricing.

### Equation 9. Benchmark Macro-Financial Alignment

$$M_t = 0.60 MU_t + 0.40 MA_t \quad (9)$$

The baseline sets  $M_t = 0.60 MU_t + 0.40 MA_t$ . The 0.60/0.40 split is a transparent normative design choice, not an empirically identified optimum; 0.50/0.50 and 0.70/0.30 are examined in sensitivity analysis. First-order return dependence is evaluated separately through the absolute rolling AR(1) coefficient.

### Equation 10. Low First-Order Return-Predictability Score

$$E_t(c\phi) = 1 - \min\{|\phi_t|/c\phi, 1\}, c\phi > 0. \quad (10)$$

$E_t(c\phi) = 1 - \min(|\phi_t|/c\phi, 1)$ , with baseline  $c\phi = 0.50$ . The constant is a bounding device rather than a hypothesis-test threshold or a universal boundary for efficiency;  $c\phi$  values of 0.25 and 0.75 are also examined.  $E_t$  measures only AR(1)-type dependence captured by Equation (6), not comprehensive weak-form or informational efficiency.

The third diagnostic uses the magnitude of the one-step-ahead ARX residual. Its scale  $\sigma_{\varepsilon,t}$  is the training-window residual standard error, calculated as the square root of  $SSE/(W-6)$  using only in-sample residuals through  $t-1$ . The date- $t$  residual is divided by that prior-data scale. A large standardised deviation means that the selected linear specification describes the realised return less closely; it may reflect omitted news, structural breaks, changing volatility, non-linearity, measurement error or misspecification and does not identify a behavioural mechanism.

### Equation 11. Standardised One-Step-Ahead Residual

$$z_t = \frac{\varepsilon_t}{\sigma_{\varepsilon,t}} \quad (11)$$

In Equation (11),  $z_t$  is the standardised one-step-ahead residual,  $\varepsilon_t$  is the realised minus conditional fitted return at  $t$ , and  $\sigma_{\varepsilon,t}$  is calculated exclusively from the preceding rolling estimation window.

#### Equation 12. Standardised Unexplained-Return Deviation

$$D_t(cz) = \min\{|z_t|/cz, 1\}, cz > 0. \quad (12)$$

$D_t(cz) = \min\{|z_t|/cz, 1\}$ , with baseline  $cz=3$ . The constant is used only to bound the influence of extreme residuals and is not a boundary between rational and irrational behaviour. Values of 2 and 4 are examined in the sensitivity analysis.

#### Equation 13. Model-Based Residual Stability

$$Q_t = 1 - D_t \quad (13)$$

$Q_t = 1 - D_t$  is the model-based residual-stability score. Higher values denote smaller standardised deviations from the selected ARX specification, not stronger investor competence or the absence of behavioural bias.

#### Time-Varying PC1 Weighting and Explained Variance

The three diagnostics  $M_t$ ,  $E_t$ , and  $Q_t$  are aggregated using rolling PCA rather than with permanently fixed weights. Within each eligible diagnostic window, the three series are mean-centred and standardised, a correlation matrix is formed, and the first eigenvector is extracted. The return series is not included in PCA itself. Equal one-third weights are reported as a direct robustness check on aggregation.

For each date  $t$ , the subcomponent matrix is delineated as follows:

#### Equation 14. Sub-Index Vector Equation

$$X_t = \begin{bmatrix} M_t \\ E_t \\ Q_t \end{bmatrix} \quad (14)$$

Before PCA, each diagnostic is mean-centred and standardised within the stated rolling diagnostic window. Zero-variance windows are treated as unavailable rather than assigned an arbitrary loading.

#### Equation 15. Rolling Standardisation Equation

$$Z_{s,j} = \frac{X_{s,j} - \bar{X}_{t-W+1:t,j}}{\sigma_{t-W+1:t,j}} \quad (15)$$

Here,  $j \in \{M, E, Q\}$ ; the rolling mean and standard deviation are calculated from the eligible diagnostic observations specified in the replication protocol.

The correlation matrix is calculated from the standardised diagnostic matrix:

#### Equation 16. Rolling Correlation Matrix Equation

$$C_t = \frac{1}{W-1} Z_t' Z_t \quad (16)$$

PC1 loadings and eigenvalues are obtained by eigenvalue-eigenvector decomposition:

#### Equation 17. First Principal Component Equation

$$C_t v_{1,t} = \lambda_{1,t} v_{1,t} \quad (17)$$

The eigenvector sign is arbitrary. For presentation, it is oriented so that the sum of the loadings is positive; index weights are the squared loadings, normalised to one, and are invariant to that orientation. PC1 explained variance is  $EV1_t = 100 \times \lambda_{1,t} / (\lambda_{1,t} + \lambda_{2,t} + \lambda_{3,t})$ . Squared loadings describe relative contribution to PC1 but do not imply that the diagnostics have identical economic meanings.

#### Equation 18-19. Time-Varying PC1 Weight Equation

$$w_{j,t} = \frac{v_{j1,t}^2}{\sum_{k=1}^3 v_{k1,t}^2} \quad (18)$$

$$w_{M,t} + w_{E,t} + w_{Q,t} = 1 \quad (19)$$

The time-varying weights  $w_{M,t}$ ,  $w_{E,t}$ , and  $w_{Q,t}$  apply, respectively, to benchmark macro-financial alignment, low first-order return predictability, and model-based residual stability. Their distribution, volatility and PC1 explained variance are reported in Table 5 and Appendix Figure A3.

The raw composite is calculated as follows:

### Equation 20. PC1-Weighted MBFLPI Raw Composite

$$\text{MBFLPI}_{\text{raw},t} = wM_t M_t + wE_t E_t + wQ_t Q_t. \quad (20)$$

For the ex post presentation, the raw composite is transformed to a 0–100 range.

### Equation 21. Full-Sample Min–Max Normalisation

$$\text{MBFLPI}_t = 100 \times [\text{MBFLPI}_{\text{raw},t} - \min(\text{MBFLPI}_{\text{raw}})] / [\max(\text{MBFLPI}_{\text{raw}}) - \min(\text{MBFLPI}_{\text{raw}})]. \quad (21)$$

A higher value means that, within the selected model and scaling, the return process shows greater benchmark sign concordance and fit, weaker AR(1)-type dependence and smaller standardised residual deviations. The 0–100 transformation is relative and non-cardinal. Full-sample extrema render Equation (21) an ex post visual rescaling; a recursively scaled version that uses only information available at each date is therefore reported as a robustness check.

### Model Parameters, Sensitivity and Replication Protocol

The baseline uses observed BIST sessions, a 252-observation ARX window, 0.60/0.40 sign/fit weights,  $c\phi=0.50$ ,  $cz=3$ , rolling PC1 aggregation, USD-denominated returns and full-sample ex post normalisation. Alternatives vary  $W \in \{126, 252, 504\}$ , PC1 versus equal weights, sign/fit weights of 0.50/0.50 and 0.70/0.30,  $c\phi \in \{0.25, 0.50, 0.75\}$ ,  $cz \in \{2, 3, 4\}$ , nominal-TL and HICP-deflated TL returns, and recursive scaling.

Replication proceeds by retaining only observed BIST sessions; applying the stated as-of and lag rules; constructing returns and covariate changes; estimating the rolling ARX using observations through  $t-1$ ; obtaining the date- $t$  fitted value and residual; computing  $M_t$ ,  $E_t$ ,  $D_t$  and  $Q_t$ ; estimating rolling PCA weights and EV1; and calculating raw, ex post and recursive composites. Archived file-names, raw headers, missing counts, timing limitations and the sensitivity grid are recorded in Appendix C.

**Table 5. Rolling-PC1 Explained Variance, Signed Loadings and Weight Stability**

| Metric       | Mean  | SD    | P5    | Median | P95   | Range        | Median $ \Delta $ / session |
|--------------|-------|-------|-------|--------|-------|--------------|-----------------------------|
| EV1 (%)      | 46.97 | 6.70  | 37.25 | 46.62  | 57.98 | 35.40–62.35  | 0.160                       |
| Loading M    | 0.39  | 0.53  | -0.71 | 0.68   | 0.72  | --0.80–0.80  | 0.002                       |
| Loading E    | 0.30  | 0.59  | -0.71 | 0.66   | 0.71  | 0.75–0.81    | 0.001                       |
| Loading Q    | 0.10  | 0.34  | -0.53 | 0.06   | 0.69  | ---0.76–0.81 | 0.009                       |
| Weight M (%) | 43.33 | 11.56 | 18.86 | 48.93  | 52.22 | 0.00–64.49   | 0.232                       |
| Weight E (%) | 43.72 | 11.09 | 15.12 | 48.86  | 51.42 | 0.00–66.06   | 0.166                       |
| Weight Q (%) | 12.95 | 16.43 | 0.02  | 4.00   | 49.06 | 0.00–65.47   | 0.319                       |

Note.  $N=2,609$  for every metric. EV1 and squared-loading weights are percentages; signed loadings are in their original units. The positive-sum orientation fixes only the arbitrary global eigenvector sign, so individual signed loadings may remain negative. Squared weights are non-negative.

**Table 6. Sensitivity of MBFLPI to Design Choices**

| Dimension       | Alternative             | Common N | Pearson | Spearman | Mean $ \Delta $ | Low-decile overlap |
|-----------------|-------------------------|----------|---------|----------|-----------------|--------------------|
| ARX window      | 126 sessions            | 2,609    | 0.613   | 0.626    | 9.99            | 45.2%              |
| ARX window      | 504 sessions            | 2,357    | 0.615   | 0.587    | 9.51            | 61.0%              |
| Aggregation     | Equal one-third weights | 2,609    | 0.780   | 0.767    | 9.78            | 56.3%              |
| Sign/fit mix    | 0.50 / 0.50             | 2,609    | 0.975   | 0.974    | 4.12            | 91.2%              |
| Sign/fit mix    | 0.70 / 0.30             | 2,609    | 0.978   | 0.977    | 2.84            | 92.3%              |
| AR scale        | $c\phi = 0.25$          | 2,607    | 0.891   | 0.923    | 8.81            | 68.2%              |
| AR scale        | $c\phi = 0.75$          | 2,609    | 0.978   | 0.979    | 2.94            | 92.0%              |
| Residual scale  | $cz = 2$                | 2,609    | 0.973   | 0.977    | 2.01            | 85.1%              |
| Residual scale  | $cz = 4$                | 2,609    | 0.990   | 0.991    | 4.69            | 91.2%              |
| Return currency | Nominal TL              | 2,609    | 0.462   | 0.546    | 9.71            | 32.2%              |
| Return currency | HICP-deflated TL        | 2,609    | 0.300   | 0.347    | 12.24           | 28.4%              |
| Scaling         | Recursive min–max       | 2,608    | 0.857   | 0.925    | 4.70            | 73.9%              |

Note. All statistics use dates common to both the alternative and the USD 252-session rolling PCA baseline. Correlations close to one indicate similarity, not construct validity. Currency variants use the same covariates and timing rules but a different dependent-return denomination.

## Sensitivity and Robustness Analysis

Composite indicators may be sensitive to window length, internal weighting, scaling constants, aggregation, currency denomination and normalisation. Every reported alternative is compared with the baseline on common valid dates. Pearson and Spearman correlations, mean absolute differences and bottom-decile overlap are reported as complementary diagnostics.

The sensitivity grid uses 126-, 252-, and 504-session ARX windows; rolling-PC1 and equal-one-third aggregation; alternative sign/fit, AR, and residual-scaling choices; USD, nominal-TL, and HICP-deflated TL returns; and full-sample versus recursive min-max normalisation. These comparisons test construction sensitivity and do not turn contextual event windows into causal tests.

## Independent External Benchmarking Procedure

MBFLPI is compared with published Türkiye-specific evidence that is independent of the market inputs used to construct the proxy. The 2014 S&P Global FinLit Survey and the May–June 2015 G20/OECD-INFE survey commissioned by the Capital Markets Board predate the first valid composite observation on 7 September 2015 and are therefore used only as historical content-domain benchmarks.

For survey waves inside the valid sample, daily MBFLPI is averaged over each disclosed fieldwork window without interpolating survey scores or inserting them into the ARX-PCA construction. Pearson correlation, Spearman rank correlation and the direction of change are reported separately for the TEB-Boğaziçi University series and the independent FODER-Visa Türkiye/Ipsos series because their instruments and scales are not interchangeable. The 2022 TEB observation is contextual only because an exact fieldwork window could not be verified from the accessible report metadata.

The Capital Markets Board's balanced-equity-investor count and domestic market-value share are added as criterion-related measures of market

participation and composition, not as financial-literacy scores. Participation and investor composition also reflect wealth, access, transaction costs, public offerings, incentives, risk tolerance and market conditions. With only four and three matched survey waves, respectively, the survey correlations are exploratory and cannot establish individual-level measurement equivalence, predictive validity or causality.

## Findings

The revised analysis reports three rolling diagnostics: benchmark macro-financial alignment, low first-order return predictability and standardised unexplained-return deviation, whose inverse enters the composite as model-based residual stability. MBFLPI combines these observable features into an indirect, market-based proxy for financial literacy. It does not directly measure investors' knowledge, motives, or psychological states, and it cannot distinguish retail from institutional or domestic from foreign investors.

Benchmark macro-financial alignment combines the share of coefficients that satisfy the four maintained sign conditions with the clipped adjusted R-squared. A higher value means that more coefficients have the pre-specified signs and that the selected equation explains more return variation in the relevant window. Because coefficient signs can change across macroeconomic regimes and variables may respond simultaneously to common news, the score describes conditional comovement under the maintained specification rather than correct or incorrect interpretation by investors.

The low first-order return-predictability score is constructed from the absolute rolling AR(1) coefficient. A higher value denotes weaker estimated dependence on the immediately preceding return. It is related to a narrow weak-form question of linear predictability, but it is not a comprehensive test of the efficient-market hypothesis.

In particular, this diagnostic does not incorporate variance-ratio tests, higher-order autocorrelation, volatility clustering, a general random-walk

test or a direct estimate of adjustment speed. A high score should therefore be read only as weakly estimated first-order dependence within the rolling window (Fama, 1970; Lo and MacKinlay, 1988).

The standardised unexplained-return deviation records the magnitude of the one-step-ahead residual relative to the training-window residual scale; its inverse enters MBFLPI as residual stability. A large value indicates that the included variables and the linear specification do not well describe the realised return. It cannot by itself identify overreaction, herding, panic, speculation, irrational optimism or pessimism.

A higher MBFLPI, therefore, denotes, within the selected specification and normalisation, greater conformity with the maintained sign and fit criteria, weaker AR(1)-type dependence, and smaller standardised residual deviations. A lower value denotes the reverse combination. Monthly averages are used in Figure 3 for readability. At the same time, daily series and PCA diagnostics appear in Appendix B. Contextual event markers organise descriptive comparisons only and do not identify causal effects or transmission channels.

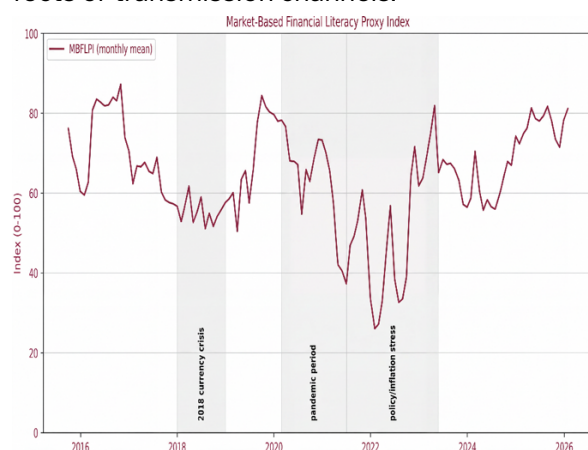


**Figure 3. Monthly mean MBFLPI with descriptive regime shading (0–100; September 2015–January 2026). Shaded intervals provide historical context and are not causal event estimates.**

After reconstructing the panel on 3,133 observed BIST sessions, the 252-session ARX plus trailing 252-diagnostic PCA baseline is available from 7 September 2015 to 30 January 2026 (N=2,609). The ex post-normalised MBFLPI has a mean of 63.80 and a standard deviation of 14.67.

Its 0 and 100 extrema are mechanical consequences of min–max scaling and are not external performance thresholds.

Across the baseline windows, PC1 explains an average of 46.97 per cent of diagnostic variance (median 46.62; range 35.40–62.35 per cent). Mean squared-loading weights are 43.3 per cent for M, 43.7 per cent for E and 12.9 per cent for Q. Q's median weight is only 4.0 per cent, and its standard deviation is 16.4 percentage points. Together with low pairwise diagnostic correlations (M–E 0.092, M–Q -0.047, E–Q -0.019), this shows that PCA weights are time-varying rather than uniformly stable.

Internal calibration changes are comparatively similar to the baseline: their Spearman correlations range from 0.912 to 0.991. Equal one-third aggregation yields Spearman 0.767. Window length is more material: the 126- and 504-session variants yield Spearman correlations of 0.626 and 0.587, respectively.

Return denomination is the largest source of divergence. Relative to the USD baseline, nominal-TL and HICP-deflated TL variants have Spearman correlations of 0.546 and 0.347, with bottom-decile overlaps of 32.2 and 28.4 per cent. The index is therefore not invariant with respect to the investor-currency perspective, and USD results must not be generalised across all investor groups.

For the USD baseline, descriptive regime means are 62.18 during the 2018–2019 currency stress, 61.99 during the March 2020–June 2021 pandemic interval, 51.24 during the July 2021–May 2023 policy/inflation stress, and 68.80 from June 2023 to the sample end. These windows overlap multiple developments and provide descriptive context only.

The corrected baseline is only moderately correlated with the archived weekday-grid, fixed-weight series (Pearson: 0.462; Spearman: 0.411), confirming that the calendar, timing, and PCA corrections materially change the measurement. On 15 July 2016, for example, Q fell to 0.00, but its rolling PCA weight was only 0.2 per cent, and the composite remained 75.4. This example also shows why a residual event and a composite movement

cannot be treated as the same finding: a time-varying PCA weight can mute or amplify a diagnostic.

### Independent External Benchmark Comparison

Table 7 compares the proxy with published Türkiye-specific financial literacy surveys and official statistics on investor participation. The comparison uses the survey fieldwork period rather than the publication year whenever dates are disclosed; no report score is treated as a daily series, and no survey scales are pooled.

Accordingly, the published reports strengthen the study by making the external evidence testable and transparent, but they do not validate MBFLPI as a direct measure of financial literacy. The discordant TEB result is retained as a substantive limitation rather than being removed, re-signed or used to recalibrate the index after observing the correlations. Over 125 common months, neither the domestic investor count (Pearson  $r=0.098$ ,  $p=0.279$ ; Spearman  $\rho=-0.062$ ,  $p=0.495$ ) nor the domestic market-value share (Pearson  $r=-0.161$ ,  $p=0.072$ ; Spearman  $\rho=0.006$ ,  $p=0.951$ ) supplies criterion-related validation; both remain market-structure context.

**Table 7. Published Türkiye Benchmarks and External-Comparison Results**

| Published benchmark                                         | Survey/reference period                                                                                                                                    | Published finding                                                                                                    | Time-matched MBFLPI and assessment                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| S&P Global FinLit Survey (2014)                             | 16 May–24 June 2014; adults 15+; N=1,002                                                                                                                   | 24% met at least 3 of 4 concept criteria                                                                             | No overlap: valid MBFLPI begins 7 September 2015. Historical content-domain benchmark only.                                                                                                                                                                                                                                        |
| G20/OECD-INFE–Capital Markets Board (2015)                  | May–June 2015; adults 18–79; N=3,003                                                                                                                       | 12.5/21 overall: knowledge 4.6/7; behaviour 4.8/9; attitudes 3.1/5                                                   | No overlap with the disclosed fieldwork window. Historical contextual benchmark only.                                                                                                                                                                                                                                              |
| TEB–Boğaziçi University Financial Literacy and Access Index | 2016 May–July (N=1,526); 2017 May–July (N=1,510); 2018 September–October (N=1,524); 2020 August–September (N=1,506); national age-18+ face-to-face samples | Survey score / fieldwork-period MBFLPI mean — 2016: 60.1/82.21; 2017: 60.8/66.46; 2018: 61.5/53.04; 2020: 60.8/64.35 | Pearson $r=-0.992$ ( $p=0.008$ ); Spearman $\rho=-0.949$ ( $p=0.051$ ); direction agreement 0/3. Does not support convergent validity.                                                                                                                                                                                             |
| TEB–Boğaziçi University (2022)                              | 2022 report; fieldwork dates not disclosed in the accessible report metadata                                                                               | Financial Literacy Index = 62.1/100                                                                                  | Annual MBFLPI mean=44.39 (252 sessions). Context only; excluded from the fieldwork-matched test.                                                                                                                                                                                                                                   |
| FODER–Visa Türkiye / Ipsos Financial Literacy Survey        | 17 March–21 May 2017 (adult analytic N=1,951); January–February 2019 (N=1,918); September–October 2021 (survey N=2,006); national face-to-face samples     | Survey score / fieldwork-period MBFLPI mean — 2017: 55/66.83; 2019: 55/59.40; 2021: 54/57.11                         | Pearson $r=0.683$ ( $p=0.522$ ); Spearman $\rho=0.866$ ( $p=0.333$ ); direction agreement 1/2. Positive but statistically uninformative at $n=3$ .                                                                                                                                                                                 |
| Capital Markets Board balanced-equity-investor series       | Monthly overlap, September 2015–January 2026; N=125                                                                                                        | Domestic balanced-equity-investor count and domestic market-value share                                              | Investor count vs MBFLPI: Pearson $r=0.098$ ( $p=0.279$ ), Spearman $\rho=-0.062$ ( $p=0.495$ ), change correlation=0.052 ( $p=0.565$ ). Domestic share: Pearson $r=-0.161$ ( $p=0.072$ ), Spearman $\rho=0.006$ ( $p=0.951$ ), change correlation=0.012 ( $p=0.896$ ). Criterion-related context only; no support for validation. |

*Note. Values separated by a slash are the published survey score and the MBFLPI mean over the disclosed fieldwork window. MBFLPI is sample-normalised; numerical equality with a survey score is neither expected nor interpreted as agreement. The S&P and OECD/INFE observations are outside the valid composite period. Sources: Klapper, Lusardi and van Oudheusden (2015); OECD (2017); TEB and Boğaziçi University (2016–2022); FODER, Visa Türkiye and Ipsos (2017, 2019, 2021); Capital Markets Board of Türkiye (n.d.).*

The two independent survey families do not yield consistent validation results. Across the four fieldwork-matched TEB–Boğaziçi University waves, the association is negative (Pearson  $r=-0.992$ ,  $p=0.008$ ; Spearman  $\rho=-0.949$ ,  $p=0.051$ ; direction agreement 0/3). Across the three FODER–Visa Türkiye/Ipsos waves, the association is positive but statistically uninformative (Pearson  $r=0.683$ ,  $p=0.522$ ; Spearman  $\rho=0.866$ ,  $p=0.333$ ; direction agreement 1/2). The very small number of waves, the different individual-level instruments, and the aggregate daily nature of MBFLPI preclude a formal claim of convergent validity.

### Implications for the Market-Based Financial Literacy Proxy

The study retains financial literacy as its motivating concept but operationalises it as an indirect market-based proxy. It observes aggregate pricing outcomes rather than individuals' knowledge, skills, attitudes or behaviour. The present results, therefore, describe MBFLPI movements and should not be interpreted as direct changes in the literacy of BIST 100 investors.

The residual component is useful as a model diagnostic because it identifies dates on which the

selected ARX specification leaves unusually large return departures. The same pattern may arise from omitted public news, sectoral information, time-varying volatility, structural breaks or non-linearity. Behavioural explanations can motivate later tests, but they are not identified findings of this analysis.

The composite and its diagnostics vary across the sample and around some periods of financial, political and geopolitical stress. These co-movements show that the selected pricing characteristics are state-dependent and can motivate more specific hypotheses. They do not show that investors ignored fundamentals, decomposed risk premia incorrectly, or acted in panic; nor does a subsequent recovery establish a return to economic equilibrium.

For regulators, portfolio managers and analysts, MBFLPI may serve as an initial, complementary monitoring screen linking return dependence, macro-financial co-movement and model adequacy. Any diagnosis of individual financial literacy, market inefficiency, behavioural risk, or political risk transmission nevertheless requires supplementary tests, direct variables, and an identification design.

## Conclusions

This study develops a Market-Based Financial Literacy Proxy Index for the BIST 100. It tracks time variation in three features of aggregate pricing: conformity with maintained macro-financial coefficient signs and model fit, first-order return dependence, and standardised departures from a rolling ARX specification. It is a complementary market-level proxy, not a direct measure of individual investors' financial literacy.

The revised empirical analysis uses actual BIST sessions, conservative availability alignment and a 252-session baseline ARX model. The benchmark macro-financial alignment score combines sign concordance and clipped fit; the low first-order return-predictability score transforms the absolute AR(1) coefficient; and model-based residual stabil-

ity is the inverse of capped standardised unexplained-return deviation. Rolling PC1 weights combine the diagnostics. These measures do not establish correct pricing, comprehensive efficiency or behavioural robustness.

The corrected USD baseline covers 2,609 composite observations and averages 63.80 on the ex post 0–100 scale. PC1 explains 46.97 per cent of variance on average, with mean M/E/Q weights of 43.3/43.7/12.9 per cent. These quantities document the behaviour of the construction; they do not validate an absolute level of market quality.

Sensitivity analysis supports a qualified conclusion. Threshold and internal-weight variants preserve rankings relatively closely, but equal weighting, rolling-window length and especially return denomination produce meaningful differences. The USD baseline records its lowest broad regime mean in July 2021–May 2023 (51.24) and a higher mean after June 2023 (68.80); nevertheless, the nominal- and real-TL variants are much less closely aligned with the USD series. Robustness is therefore strongest for internal calibration and weakest across currency perspectives.

The study does not empirically distinguish among financial, political, systemic, and geopolitical shocks. Türkiye's five-year CDS spread is a broad sovereign-risk indicator that incorporates credit, fiscal, macroeconomic, exchange-rate, liquidity, and global risk-appetite information, potentially alongside political information. Contextual events overlap and are not evaluated against formal counterfactuals; no risk-specific causal channel is therefore claimed.

The principal contribution is methodological: three transparent rolling diagnostics of aggregate pricing are integrated using time-varying PC1 weights and evaluated through a pre-specified sensitivity grid. The framework offers a reproducible screen for researchers, policymakers, regulators and market practitioners, provided it is used alongside—not in place of—direct measures of investor characteristics, market microstructure, political risk and model adequacy.

Several limitations define the scope of inference. Aggregate prices do not identify individual

knowledge or motives and cannot separate investor groups. The independent benchmark comparison is aggregate and exploratory: the four field-work-matched TEB–Boğaziçi University waves are negatively associated with MBFLPI, while the three FODER–Visa Türkiye/Ipsos waves yield a positive but statistically uninformative association. Monthly Capital Markets Board investor-count and domestic-share indicators also provide no criterion-related validation. These mixed results do not support convergent validity. The earlier S&P and OECD/INFE–Capital Markets Board observations are historical because they predate the valid composite. USD returns embed exchange-rate movements. ARX coefficients are conditional associations; the maintained signs may change meaning across regimes; large residuals have multiple explanations; and the industrial-production timing rule is a conservative one-month approximation rather than an exact first-release-vintage mapping. The index also depends on window length, internal weights, thresholds, aggregation, return denomination and normalisation.

In conclusion, MBFLPI documents time variation in a defined set of BIST 100 pricing characteristics as an indirect proxy for market-based financial literacy. Its defensible value lies in showing when benchmark macro-financial alignment and fit, low first-order return predictability and residual stability strengthen or weaken together. The published-report comparison makes an important boundary visible: the present series should not be interpreted as a direct or externally validated score of individual financial literacy. Future validation requires more frequent, consistently measured and time-matched investor survey microdata; investor composition and participation may provide supplementary criterion evidence, but cannot substitute for a literacy measure.

## Declarations

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**Data Availability:** The data that support the findings of this study are openly available in investing at <https://tr.investing.com/indices/ise-100>.

**Informed Consent:** Informed consent was not applicable because the study did not involve human participants.

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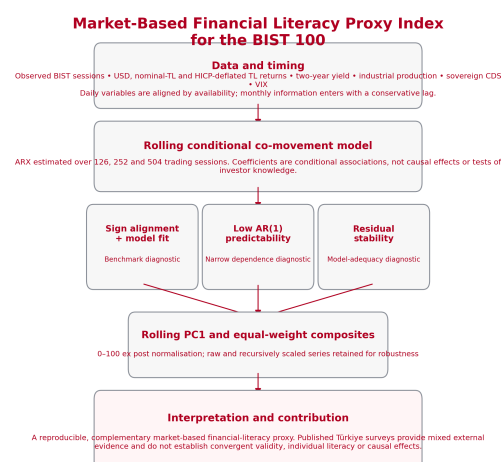
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## APPENDICES

### Appendix A. Graphical Abstract



### Appendix B. Daily Series and PCA Diagnostics

The daily plots are placed in the appendix because their observation density makes monthly averages more legible in the main text. All displayed index values use the 0–100 scale; M, E and Q are multiplied by 100 solely for graphical comparability.

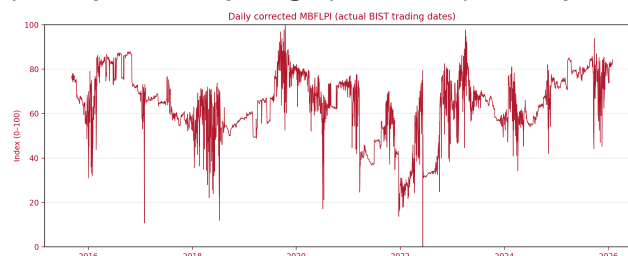


**Figure A1. Corrected daily MBFLPI on actual BIST trading sessions (0–100).**



**Figure A2. Daily benchmark alignment, low first-order return predictability, residual stability and MBFLPI (diagnostics multiplied by 100 for display).**

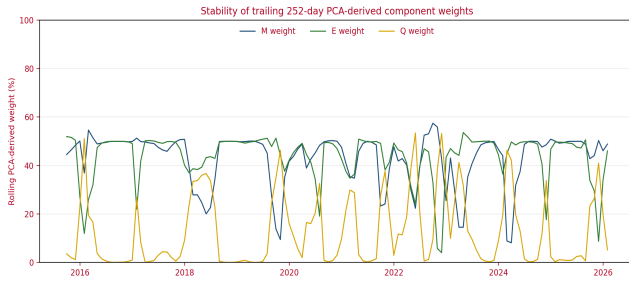


**Figure A3. Rolling 252-diagnostic-window PCA weights (per cent).**

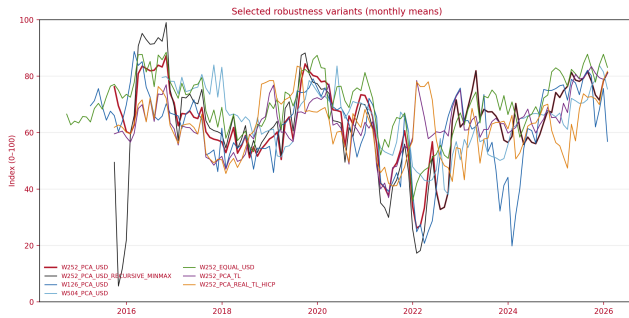


**Figure A4. Monthly means for selected design and currency variants (0-100).**

## Appendix C. Data Alignment and Replication Protocol

1. Keep only dates with an observed raw BIST 100 close; never carry the BIST level forward.
2. Align USD/TRY, the two-year yield and CDS to each BIST session using the most recent non-missing observation dated on or before the session; calculate changes after alignment.
3. Restrict VIX to the most recent non-missing US close strictly before the BIST date.
4. Collapse the supplied daily-expanded industrial-production path to calendar-month final snapshots; use the month  $m-1$  snapshot throughout month  $m$  and acknowledge that this is not exact release-vintage alignment.
5. Estimate the ARX coefficients for date  $t$  from the preceding  $W$  observations through  $t-1$ , then calculate the date- $t$  fitted value and one-step-ahead residual using the date- $t$  information state.
6. Compute M, E, D and Q under the stated clipping and threshold rules. For PCA variants, estimate PC1 on the preceding 252

valid diagnostic triplets, orient only the global eigenvector sign, square the loadings and apply the resulting weights to the current triplet.

7. Retain the raw composite; report full-sample 0-100 scaling as ex post presentation and running-minimum/running-maximum scaling as the real-time robustness alternative.

Industrial production and HICP limitations. The archived industrial-production and HICP sources are latest-vintage, daily-expanded paths and do not preserve official historical release timestamps or first-release vintages. Monthly collapsing and a one-month lag remove artificial daily increments and prevent future-month observations from entering early, but they cannot reconstruct real-time vintages. No announcement, surprise, or revision-free claim is made.

**Table A1. Calendar, Coverage and Alignment Audit Trail**

| Replication item                   | Recorded value or rule                                                                                                                          |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| weekday_grid_rows                  | 3262                                                                                                                                            |
| actual_bist_trading_rows           | 3133                                                                                                                                            |
| weekday_rows_removed_as_nontrading | 129                                                                                                                                             |
| first_bist_date                    | 2013-08-01                                                                                                                                      |
| last_bist_date                     | 2026-01-30                                                                                                                                      |
| ip_monthly_snapshots               | 150                                                                                                                                             |
| hicp_monthly_snapshots             | 164                                                                                                                                             |
| calendar_rule                      | Rows with non-missing raw BIST100_Close only; BIST was never forward-filled.                                                                    |
| market_alignment_rule              | USDTRY, 2Y rate and CDS: latest non-missing value on or before each BIST date; changes computed after alignment.                                |
| vix_alignment_rule                 | Latest non-missing VIX observation strictly before each BIST date (previous available U.S. close); changes computed after alignment.            |
| industrial_production_rule         | The last supplied observation in month $m$ is used on every BIST trading day in month $m+1$ ; updates occur on the first BIST day of the month. |
| real_return_rule                   | BIST level deflated by TR HICP (2025=100); month- $m$ HICP snapshot used in month $m+1$ . Latest-vintage monthly index-level robustness proxy.  |

Reproducibility note. The unrounded daily baseline, monthly averages, variant indices, PCA diagnostics, descriptive statistics, ADF diagnostics, regime summaries and sensitivity correlations were generated from the archived source workbooks. Full-sample scaling is not used inside the ARX or PCA estimation steps.

## Appendix D. Sensitivity Grid and Interpretation Boundaries

The pre-specified grid varies the ARX window (126/252/504 sessions), final aggregation (rolling PC1/equal thirds), sign-concordance versus fit weights (0.50/0.50, 0.60/0.40 and 0.70/0.30), AR scaling (0.25/0.50/0.75), residual scaling (2/3/4), return denomination (USD/nominal TL/HICP-deflated TL), and full-sample versus recursive normalisation. Comparisons use common dates. Pearson correlation assesses linear similarity, Spearman correlation assesses rank preservation, mean absolute difference reports scale divergence, and bottom-decile overlap assesses whether low-index observations recur. None is a causal event test.

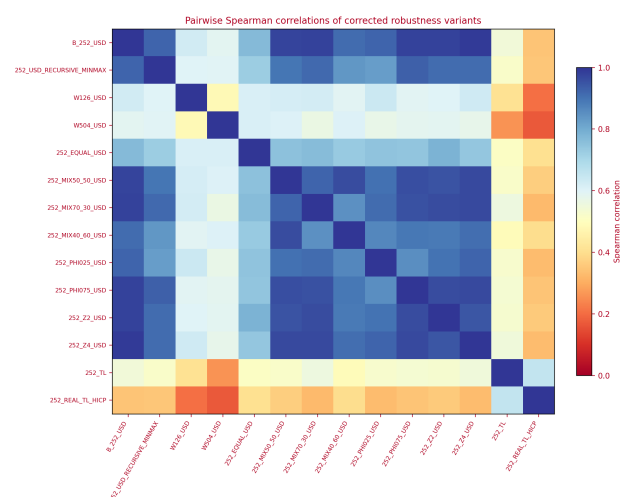


**Figure A5—correlation-based sensitivity summary for the reported variants.**