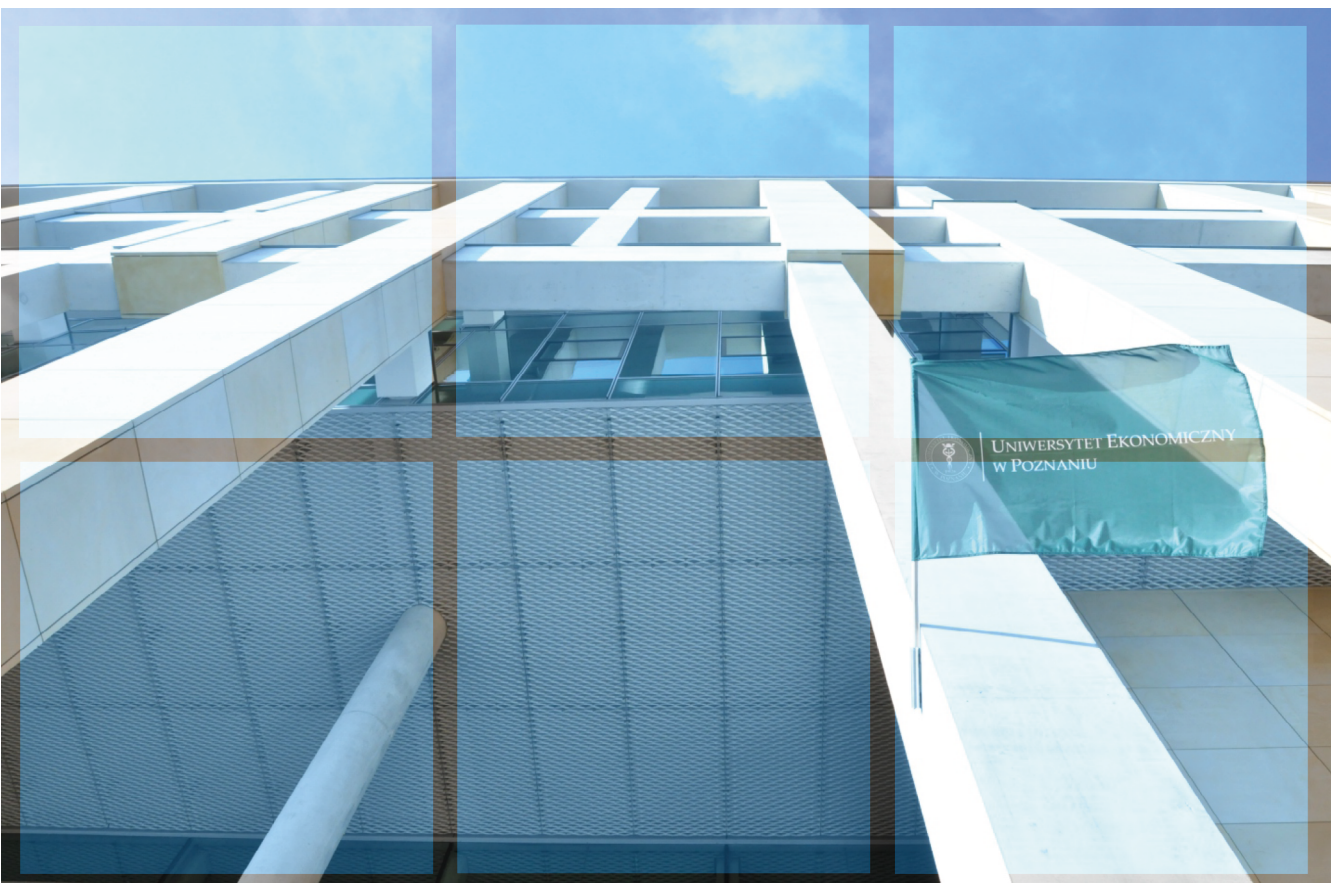


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Preface

Welcome to the latest issue of *Research Papers in Economics and Finance*, published by the Poznań University of Economics and Business Press. This edition includes six peer-reviewed articles offering important perspectives on current discussions in the fields of economics and finance. The research covers a variety of topics, including investment strategies, financial literacy, digital transformation, monetary policy, and international trade finance.

We want to express our gratitude to the authors for their scholarly contributions and to the reviewers for their commitment and expertise throughout the review process. We hope that the articles presented in this issue will inspire further research, encourage thoughtful discussion, and provide inspiration for both academics and practitioners.

The issue opens with **Assessing the effectiveness of Greenblatt's Magic Formula across international stock markets: A literature review** by Krzysztof Podgórski of the University of Economics in Katowice, Poland. Through a comprehensive review of the existing literature, the author examines the effectiveness of Joel Greenblatt's Magic Formula as an investment strategy across international equity markets. The analysis indicates that the strategy frequently outperforms benchmark indices, although its effectiveness is influenced by factors such as transaction costs, firm size, prevailing market conditions, and modifications to the underlying metrics.

The second article, **To know or not to know? How societal factors and education shape the financial awareness and knowledge of students**, by Maksymilian Czauderna of Wrocław University of Economics and Business, Poland, investigates the determinants of financial awareness among students. The findings highlight the importance of both social and individual learning processes, as well as the effective use of educational resources. The study suggests that policymakers and educators should place greater emphasis on practical engagement and real-world exposure to financial risk to strengthen financial literacy.

The third contribution, **The impact of digital transformation on enhancing service quality dimensions in higher education: An applied study at the faculty of economics, Setif 1 University**, co-authored by Saadi Ayad of Ferhat Abbas

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University Setif 1, Algeria, and Mohamed Fouad Henni of the University of Tipaza, Algeria, examines the role of digital transformation in improving academic and administrative services. Focusing on the Faculty of Economic Sciences at Setif 1 University, the study demonstrates how digitalisation can enhance service quality by streamlining organisational processes and improving interactions between faculty members and students. The authors further emphasise the significance of organisational culture in facilitating successful digital transformation.

The fourth article, **A theoretical fundamental model of USD/CAD, gold spot and gold futures with interest rates, growth and financialisation**, by Mykola Yaremenko of the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, presents a three-equation structural model linking the USD/CAD exchange rate with spot and futures gold prices. The paper derives the model’s reduced-form properties and explores its key theoretical implications, including the feedback mechanisms connecting exchange rates and gold markets. Preliminary analyses provide support for the model and reveal meaningful interdependencies among the variables considered.

Next, Patryk Kołbyko of Maria Curie-Skłodowska University in Lublin, Poland, contributes **From r^* to monetary policy stance: Evidence from Poland**. The study estimates Poland’s time-varying natural real interest rate and natural-rate gap between the first quarter of 2010 and the first quarter of 2025 using a semi-structural state-space model. Incorporating survey-based inflation expectations, the author then examines the macroeconomic effects of changes in the natural-rate gap through a structural vector error-correction framework. The findings suggest that, while the natural-rate gap is a useful indicator for assessing the stance of monetary policy, it is not sufficient to explain all fluctuations in the Polish economy.

The issue closes with **Fiscal policy and trade finance in emerging economies: Evidence from Africa** by Andrew Aondohemba Chenge of the Federal University Wukari in Taraba State, Nigeria. The paper addresses the trade finance challenges faced by African economies, examining how fiscal policy can help overcome barriers such as financing gaps, regulatory hurdles, exchange rate volatility, and macroeconomic instability. The findings indicate that strategic public spending and well-designed tax policies can foster a more favourable trade finance environment by reducing lender risk and enhancing the financial stability of trading companies.

This issue includes articles that offer various perspectives on the significant challenges and developments affecting the current economic and financial landscape. We believe readers will find these contributions informative and thought-provoking. We hope that they will inspire further research and discussions within the academic community.

Yours sincerely

Agata Kliber
Editor



Assessing the effectiveness of Greenblatt's Magic Formula across international stock markets: Literature review

 Krzysztof Podgórski¹

Abstract

This article presents a comprehensive literature review assessing the effectiveness of Joel Greenblatt's Magic Formula in international equity markets. The strategy is a value-investing approach based on return on capital (ROC) and earnings yield (EY) metrics. Its primary objectives are to evaluate whether the strategy generates excess returns and to identify factors influencing its performance. The analysis synthesises empirical studies from the US, European (primarily Nordic), Brazilian and Asian markets, incorporating methodological considerations such as data sources, investment universes and systematic biases (e.g. look-ahead bias and survivorship bias). Key findings reveal that the Magic Formula outperforms benchmarks in most markets; however, its effectiveness is contingent on transaction costs (frequently eroding alpha), firm size, market conditions and metric modifications. Simpler strategies (e.g. those relying solely on EY) occasionally yield superior results. The review concludes that the Magic Formula represents a robust, albeit imperfect, tool for exploiting stock market inefficiencies. Future research directions include analyses of post-2020 periods, formula modifications and hybrid approaches.

Keywords

- Greenblatt's Magic Formula
- value investing
- international equity markets
- return on capital
- earnings yield

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Introduction

Value investing, pioneered by Benjamin Graham, has long presented an intellectual and practical challenge for investors. Its core principle – buying high-quality assets at prices below their intrinsic value – is intuitively straightforward yet exceedingly difficult to implement systematically in practice (Petrova, 2015). The primary impediment is the efficient market hypothesis (EMH), as formulated by Eugene Fama (1970), which in its semi-strong form posits that stock prices instantaneously incorporate all publicly available information. Under this framework, the systematic identification of undervalued securities and the attainment of excess returns over the long term become infeasible (Basu, 1977).

In response to this complexity, Joel Greenblatt – a hedge fund manager and adjunct professor at Columbia Business School – introduced the Magic Formula in his book *The little book that beats the market* (Greenblatt, 2006). This strategy seeks to establish a simple, rules-based framework for value investing that systematises the identification of companies exhibiting two essential attributes: high quality and attractive valuation. Greenblatt's approach distils to a straightforward principle: “buy good companies at bargain prices”. By eschewing subjective assessments, the strategy relies exclusively on two quantitative metrics: return on capital (ROC) and earnings yield (EY) (Jannah & Imansya, 2019).

Empirical studies across international markets demonstrate that Greenblatt's Magic Formula has consistently delivered positive outcomes to date (Abbey & Larkin, 2012). For instance, research on the Indonesian market revealed a compound annual growth rate (CAGR) of 33.3% for the strategy, substantially outperforming benchmarks such as the IHSG (Sasmitapura et al., 2022). In Brazil, Sweden and other regions, annually rebalanced portfolios comprising 10–30 stocks frequently generated excess returns relative to local benchmarks; a Swedish study reported a Sharpe ratio of 0.247 for the Magic Formula versus 0.15 for the broader market (Gustavsson & Strömberg, 2018), while a Brazilian analysis documented statistically significant Capital Asset Pricing Model (CAPM) alpha of approximately 1% per month (de Paula, 2016). Numerous investigations further suggest that the Magic Formula yields robust returns irrespective of market conditions, including episodes of financial distress (Håkansson & Kvarnmark, 2017). Moreover, variations in portfolio size, stock weighting or rebalancing frequency do not eliminate the potential for outperformance (de Paula, 2016; Vestre & Wikheim, 2022).

This review article provides a comprehensive synthesis of studies evaluating the effectiveness of Greenblatt's Magic Formula across international markets and diverse time periods, critically examining its global robustness and identifying recurring factors affecting its performance, including metric modifications, transac-

tion costs and market systems. It further examines whether the strategy generates excess returns and identifies key factors moderating its performance.

The article comprises six sections. The first provides an introduction to the effectiveness of Greenblatt's Magic Formula. The second outlines the foundational assumptions of Greenblatt's approach. The third synthesises the literature on the Magic Formula's performance in international markets. The fourth details the methodology employed for the literature review. The fifth offers a critical analysis of the extant studies, accompanied by a discussion. The sixth presents concluding remarks, delineates the review's limitations, and suggests avenues for future research.

1. The foundational assumptions of Greenblatt's approach

A thorough understanding of the calculation of key metrics and the stock selection process is essential for evaluating the Magic Formula's capacity to generate excess returns across varied market conditions. The strategy rests on two foundational pillars: quality and price. Greenblatt specified dedicated metrics for each, designed to mitigate distortions arising from differing capital structures and tax regimes, thereby enabling more objective cross-company comparisons (Greenblatt, 2006).

The first metric, return on capital (ROC), measures the quality and profitability of a firm's operating activities. Greenblatt employs a precise formula to evaluate how efficiently a company generates earnings from its invested tangible capital (Kątnik, 2011). The ROC computation is presented in Formula 1.

$$\text{ROC} = \frac{\text{EBIT}}{\text{NWC} + \text{Net PP\&E}} \quad (1)$$

where:

- EBIT – earnings before interest and taxes,
- NWC – net working capital, calculated as current assets minus current liabilities,
- Net PP&E – net tangible property, plant and equipment, derived from tangible fixed assets minus accumulated depreciation and accumulated impairment losses (Sedova et al., 2020).

Greenblatt deliberately employs EBIT to evaluate a firm's operating profitability independent of its capital structure (interest expenses) and prevailing tax rates.

The sum of NWC and Net PP&E represents the tangible capital invested in core operations. Excluding intangible assets ensures reflection of the genuine physical capital essential for conducting business (Wielicki & Baum, 2009).

The second metric, earnings yield (EY), captures the valuation attractiveness of a stock (Arkan, 2016). It indicates how inexpensive a firm is relative to its operating earnings, as shown in Formula 2.

$$EY = \frac{EBIT}{EV} \quad (2)$$

where:

EV – enterprise value, market capitalisation plus interest-bearing debt minus cash and cash equivalents (Uggedal, 2009).

EBIT is employed in the earnings yield calculation for the same reasons as in the ROC metric. Enterprise value (EV), in turn, is defined as market capitalisation plus interest-bearing debt minus cash and cash equivalents. Employing EV rather than equity value alone (as in the traditional price-to-earnings ratio) is critical, as it facilitates comparisons across firms with differing leverage levels (Rutkowski, 2002). This approach incorporates both the cost of acquiring the equity and the assumption of the firm's debt, thereby providing a more comprehensive view of the total acquisition cost of the enterprise (Koller et al., 2005).

The stock selection process under Greenblatt's Magic Formula is entirely mechanical and relies on a ranking system, thereby eliminating subjective judgment in investment decisions. It comprises the following steps:

- **Step 1:** All firms in the analysed market are ranked by return on capital (ROC) in descending order. The firm with the highest ROC receives rank 1, the next receives rank 2, and so on.
- **Step 2:** The same firms are ranked separately by earnings yield (EY), also in descending order. The firm exhibiting the highest EY is assigned rank 1.
- **Step 3:** For each firm, the two ranks obtained in Steps 1 and 2 are summed.
- **Step 4:** The portfolio is constructed by selecting the 20–30 firms with the lowest sum of ranks. These firms represent the optimal combination of high operating quality and attractive valuation.

The standard implementation of the Magic Formula assumes a one-year holding period and annual portfolio rebalancing. The companies in the portfolio have equal weightings. At the end of each year, existing positions are liquidated, and the entire ranking and selection process is repeated to construct a new portfolio. Following Greenblatt's (2006) original recommendations, financial firms (e.g. banks

and insurance companies) and utilities are systematically excluded from the investment universe. This exclusion stems from the distinctive nature of their business models and financial reporting practices – notably the high leverage employed by financial institutions – which renders the ROC and EY metrics less comparable with those of firms in other sectors.

2. Literature review

This literature review contributes to the ongoing discourse on the effectiveness of Greenblatt's Magic Formula by synthesising empirical findings from studies conducted across diverse international markets. The results are organised geographically to facilitate cross-market comparisons while accounting for region-specific characteristics. The analysis begins with the US market – the original testing ground for the strategy – and proceeds through various European markets to the dynamic emerging markets.

The starting point for the subsequent analysis is the original backtest results reported by Joel Greenblatt himself (2006). In his book, he demonstrated that from 1988 to 2004, a Magic Formula portfolio constructed on the US market delivered an average annual return of 30.8%, compared with just 12.4% for the broad S&P 500 index over the same period. Although performance varied with market-capitalisation thresholds, the strategy consistently outperformed the broader market.

Subsequent studies have largely corroborated the Magic Formula's ability to generate excess returns. For instance, Alberg and Seckler (2015), employing comparable sample periods and data sources, produced results that reaffirmed the strategy's outperformance, albeit typically at a magnitude lower than originally reported by Greenblatt. These disparities primarily arose from variations in the definition of the investment universe and backtesting methodology. Nonetheless, a broad consensus emerged that the strategy delivered both statistically and economically significant alpha relative to passive benchmark investing.

Empirical studies on European markets overwhelmingly corroborate the effectiveness of Greenblatt's Magic Formula, albeit with notable nuances. The Nordic markets have proven particularly conducive to testing the strategy's performance (Persson & Selander, 2009). Sistonen (2014), examining Finland, Sweden, Norway and Denmark over the 2000–2011 period, documented an average annual net return (after taxes and transaction costs) of 29.4% for the Magic Formula, compared with only 7.6% for the FTSE Nordic Value Index. Vestre and Wikheim (2022), analysing the Norwegian market from 2003 to 2022, reported a statistically significant monthly CAPM alpha of 0.50%, confirming the strategy's ability to generate risk-

adjusted excess returns. Davydov et al. (2016), studying Finland between 1991 and 2013, similarly found that the Magic Formula outperformed the broader market by 5.63 percentage points annually (19.26% versus 13.63%). Crucially, however, they observed that a simpler value strategy based solely on the EBIT/EV (earnings yield) ratio delivered even stronger performance (20.57%) over the same period. This finding raises important questions about whether the quality component (ROC) genuinely adds incremental value beyond a pure low-valuation approach.

The Swedish market has been examined in several studies that consistently document significant outperformance of Greenblatt's Magic Formula. Both Goumas and Källström (2010) as well as Max and Svanberg (2019) found that Magic Formula portfolios substantially outperformed the OMXSPI benchmark. Notably, Max and Svanberg (2019), using data spanning 2002–2019, reported an average annual return of 19.2% for the strategy versus only 5.7% for the broad Swedish index. Empirical evidence from emerging and Asian markets further substantiates the effectiveness of Greenblatt's Magic Formula, although performance exhibits greater heterogeneity and appears more sensitive to prevailing market conditions. On the Brazilian market, studies uniformly document substantial outperformance of the strategy. Both de Paula (2016) and Silva et al. (2020) found that Magic Formula portfolios generated significantly higher returns than the local Ibovespa and IBrX-100 benchmarks. Specifically, Silva et al. (2020) reported an annualised return of 11.06% for the strategy over the 2007–2017 period, compared with only 5.04% for the Ibovespa.

Empirical investigations in Asian markets reveal a more heterogeneous picture, yet the majority still support the effectiveness of Greenblatt's Magic Formula. On the Hong Kong market, Fu and Xia (2015) documented that a portfolio comprising the top decile of stocks ranked by the Magic Formula delivered an impressive average monthly return of 2.53% over the 2001–2014 period. Results from the Indonesian market proved particularly sensitive to the sample period. Jannah and Imansyah (2019), using data from 2013–2018, reported significant outperformance of the strategy. By contrast, Setiawan et al. (2023) found that during the adverse market conditions of 2018–2021, a Magic Formula portfolio posted a negative annualised return of –1.72%; nevertheless, this still exceeded the benchmark return of –3.26%. Finally, Sasmitapura et al. (2022) restricted their investment universe to LQ45 constituents between 2016 and 2020 and concluded that the strategy failed to outperform the broader IHSG index, indicating that performance may be contingent on the breadth and composition of the investment universe.

Although the majority of empirical studies demonstrate that Greenblatt's Magic Formula generates excess returns relative to broad market benchmarks in range between 5.63% and 21.80%, the considerable heterogeneity in reported performance underscores the importance of a more detailed examination of methodological choices and moderating factors. These issues are addressed in the subsequent sections of this article.

3. Methodology employed for the literature review

The publication search strategy was founded on the utilisation of esteemed international databases, including Scopus, Web of Science and Google Scholar. These databases facilitate access to peer-reviewed scientific papers within the domains of finance and accounting. The identification of relevant articles was facilitated by the employment of the following key search terms: 'Greenblatt Magic Formula', 'magic formula investing', 'return on capital', 'earnings yield', 'value investing', and their equivalents. The search encompassed articles published subsequent to 2006, the date of publication of Greenblatt's original work.

In order to ensure the reliability and integrity of the research, precise inclusion and exclusion criteria were applied to the publications. The analysis encompassed works that satisfied the following criteria:

- they conducted empirical tests of the effectiveness of the Greenblatt strategy or its modifications;
- they were published in peer-reviewed scientific journals or as master's and doctoral theses at recognised universities;
- they covered clearly defined time frames and markets.

Articles of a purely theoretical nature, as well as popular science publications that lack methodological rigour, were excluded from consideration.

A further analysis of the methodologies employed in the collected publications was conducted. This section examines the standard methodologies employed in empirical studies of Greenblatt's Magic Formula and highlights critical methodological challenges that affect the comparability and robustness of reported findings. A thorough understanding of these issues is indispensable for conducting a rigorous critical assessment of the literature. The primary concerns include:

- data sources,
- investment universe,
- systematic biases (look-ahead bias and survivorship bias),
- portfolio construction and rebalancing procedures.

The quality and coverage of data constitute the cornerstone of any robust empirical investigation (Kowerski & Charkiewicz, 2021). Across the reviewed studies, researchers predominantly relied on established professional financial databases, including Compustat (S&P Global), Refinitiv Datastream (formerly Thomson Reuters) and Bloomberg.

A critical determinant of reported performance is the precise definition of the investment universe. Variations in this definition are a primary source of cross-study discrepancies. The principal dimensions include market-capitalisation thresholds

and sector exclusions. Greenblatt (2006) explicitly demonstrated that returns varied substantially depending on whether the strategy was applied to the full universe of stocks or restricted to firms with a market capitalisation exceeding USD 1 billion. Many subsequent studies deliberately concentrate on mid- and large-cap segments to mitigate liquidity concerns; however, this approach may exclude the very small-cap segment in which the Magic Formula has historically exhibited its strongest outperformance. Although the systematic exclusion of financial firms and utilities remains standard practice – consistent with Greenblatt’s original methodology – some investigations deviate from these criteria or implement them inconsistently, thereby hindering direct comparability of results.

Backtesting carries the risk of several systematic biases that can materially inflate reported performance. Rigorous researchers, however, implement safeguards designed to mitigate these distortions (Saad, 2021). The two most prevalent and consequential biases are look-ahead bias and survivorship bias (ter Horst & Verbeek, 2007).

Look-ahead bias arises when a backtest inadvertently incorporates information that was not publicly available at the purported time of portfolio formation. A classic manifestation occurs when year-end financial data for fiscal year $T-1$ are used to rank and select stocks as of 1 January of year T , even though annual reports are typically released only in February, March or later. To eliminate this bias, rigorous studies impose a deliberate lag – commonly three to six months – between the fiscal year-end and the portfolio rebalancing date. Consequently, data for year $T-1$ are first utilised for ranking no earlier than the end of March (or more conservatively April–June) of year T (Daniel et al., 2008).

Survivorship bias arises when a backtest includes only firms that remain listed throughout the entire sample period, thereby excluding companies that were delisted due to bankruptcy, merger, acquisition or other forms of exit. Because delisted firms typically exhibit poor prior performance, their systematic omission materially inflates reported average and risk-adjusted returns. To eliminate this bias, researchers must employ point-in-time or delisting-adjusted databases that retain comprehensive historical records of all firms – both active and inactive – at each point in time. A leading example is the Compustat Point-in-Time database, which preserves the exact information available to investors on any given historical date (Baquero et al., 2009).

Another critical methodological dimension concerns portfolio construction and rebalancing. Variations in these technical specifications exert a material influence on reported performance. The literature reveals three primary areas of divergence:

1. Portfolio size – Greenblatt (2006) originally recommended holding 20–30 stocks, yet numerous studies examine substantially larger portfolios, such as the top decile or top quintile of ranked stocks (e.g. Fu & Xia, 2015).

2. Rebalancing frequency – While the canonical Magic Formula implementation employs annual rebalancing, some researchers test monthly or quarterly intervals (e.g. Blackburn & Cakici, 2017). More frequent rebalancing enables faster incorporation of new information but dramatically increases transaction costs and turnover.
3. Weighting scheme – The majority of studies adopt equal-weighted portfolios, thereby granting greater influence to smaller firms. In contrast, value-weighted (capitalisation-weighted) portfolios – more representative of market indices – typically deliver lower excess returns.

A thorough understanding of these methodological challenges and variations is indispensable for a rigorous critical evaluation and synthesis of the empirical evidence. It explains why certain studies report striking outperformance of Greenblatt's Magic Formula, while others document more modest or even inconsistent excess returns.

4. Critical analysis and discussion

The preceding literature review establishes that Greenblatt's Magic Formula has consistently generated excess returns across a wide range of international markets. Nevertheless, its effectiveness exhibits considerable heterogeneity and is contingent on multiple methodological and contextual factors. This section offers a critical examination of these determinants, situates them within the broader theoretical framework of value investing, and challenges certain foundational assumptions of the strategy. Notwithstanding the fact that this analysis is founded upon several fundamental and reputable scientific works, a significant part of the empirical evidence, especially concerning local markets, originates from unpublished theses or doctoral dissertations. This was necessary in order to create a comprehensive international synthesis, but requires careful interpretation due to their limited scientific rigour. Table 1 synthesises the key empirical findings on the performance of the Magic Formula in different markets together with the principal conclusions drawn by the respective authors.

Among the numerous factors influencing the effectiveness of Greenblatt's Magic Formula, the literature most frequently highlights four key moderators:

- firm size (small-cap vs. mid-/large-cap universes),
- transaction costs,
- prevailing market regimes, and
- modifications to the original formula.

Table 1. Summary of empirical evidence on the Magic Formula across international markets

Author(s) and year	Market	Study period	Magic Formula performance (e.g. CAGR or α)	Benchmark performance	Premium	Key conclusion
Greenblatt, 2006	United States	1988–2004	30.8%	12.4% (S&P 500)	18.4 pp	Original Greenblatt (2006) backtest confirming exceptionally high effectiveness.
Sistonen, 2014	Nordic countries	2000–2011	29.4%	7.6% (FTSE Nordic value)	21.8 pp	Exceptionally strong returns even after transaction costs and taxes.
Vestre & Wikheim, 2022	Norway	2003–2022	20.8% (alpha 0.5% monthly)	12.8% (OSEAX)	8.0 pp	Significant alpha that loses statistical significance after transaction costs.
Davydov et al., 2016	Finland	1991–2013	19.26%	13.63% (OMXH CAP GI)	5.63 pp	Outperforms the market, but simpler pure valuation strategies (e.g. EBIT/EV alone) deliver superior performance.
Max & Svanberg, 2019	Sweden	2002–2019	19.2%	5.7% (OMXSPI)	13.5 pp	Statistically and economically significant outperformance relative to the broad market index.
Silva et al., 2020	Brazil	2007–2017	11.06%	5.04% (Ibovespa)	6.02 pp	Effective, though comparable or inferior to alternative strategies (e.g. Piotroski F-score).
Fu & Xia, 2015	Hong Kong	2001–2014	2.53% (monthly)	Not applicable – comparison of top and bottom deciles of ranked stocks	–	Very high returns for top-decile (highest-ranked) portfolios.
Jannah & Imansyah, 2019	Indonesia	2013–2018	12.67%	5.31% (IDX Kompas 100 Index)	7.36 pp	Clear outperformance of the broad market index.
Blackburn & Cakici, 2017	Global markets	1991–2016	Negative or statistically insignificant for the canonical Magic Formula implementation	–	–	Standard Magic Formula ineffective globally; modified version using gross profit proves more robust.

Source: own study based on the bibliographical references listed in the table.

One commonly cited explanation for the Magic Formula's historical outperformance attributes it primarily to the size premium: equal-weighted portfolios inherently tilt toward smaller firms, which have traditionally delivered higher returns. Although the strategy does tend to perform particularly strongly among small-cap stocks, a closer examination undermines this overly simplistic view. Blackburn and Cakici (2017) provide compelling evidence from global markets that directly challenges the size-premium hypothesis. They document that CAPM alphas (and multifactor alphas) are consistently higher in value-weighted portfolios than in equal-weighted portfolios across nearly all regions (with Europe being the sole exception). The authors conclude that "the observed risk-adjusted returns are not due to the small-firm effect. Instead, large-capitalisation firms contribute significantly to the generated alpha". This finding is pivotal: the fact that the Magic Formula produces robust, and frequently superior, risk-adjusted performance precisely in the large-cap, highly liquid segment seriously undermines the notion that its success is predominantly driven by a size tilt. Consequently, the true drivers of the strategy's effectiveness must lie elsewhere – most likely in the quality and valuation characteristics captured by the ROC and EBIT/EV metrics themselves.

The Magic Formula in its canonical form exhibits full annual turnover (approximately 100%), generates substantial transaction costs – including commissions and bid-ask spreads – that are frequently ignored or understated in academic studies. This constitutes arguably the most critical practical impediment to the strategy's real-world profitability. A particularly rigorous analysis by Vestre and Wikheim (2022) on the Norwegian market illustrates this point convincingly. While their gross (pre-cost) results reveal a statistically significant monthly CAPM alpha of 0.50%, the inclusion of realistic transaction costs reduces this alpha to near zero and renders it statistically insignificant. This finding underscores a broader pattern: although the majority of academic backtests report impressive excess returns, the most robust implementations that properly account for trading frictions frequently show that economically and statistically significant outperformance largely, or entirely, disappears in practice (Blackburn & Cakici, 2017; Gustavsson & Strömberg, 2017; Vestre & Wikheim, 2022).

The effectiveness of Greenblatt's Magic Formula is not time-invariant but varies systematically with prevailing market regimes. Alberg and Seckler (2015), examining the US market over the 1973–2012 period, found that the earnings yield (EY) component – the valuation pillar – drove nearly all of the strategy's outperformance during periods of widespread market pessimism, when aggregate P/E ratios were contracting. In contrast, the return on capital (ROC) quality component contributed relatively little during such episodes. This pattern implies that the Magic Formula tends to generate its strongest excess returns when the overall market is undervalued or in recovery phases following bear markets, whereas

its relative performance weakens markedly during the late stages of bull markets dominated by high-valuation growth stocks. Consequently, the strategy exhibits its pronounced regime-dependent behaviour rather than consistent superiority across all market environments.

A primary factor contributing to the divergence in research outcomes pertains to the delineation of the investment universe. As Blackburn and Cakici (2017) observe, in a manner consistent with the insights of Fama and French (2012), substantial excess returns (alpha) within value and momentum strategies tend to be concentrated in the small-capitalisation segment. The inclusion of low-capitalisation companies, which are characterised by a lack of liquidity, in the study may result in the artificial inflation of the theoretical results of the strategy, thereby rendering them unattainable in practice. This hypothesis is corroborated by Gustavsson and Strömberg (2017), who emphasise that small and illiquid companies, which are inaccessible to large institutional investors, pose a significant implementation risk. Research that restricts the universe to medium and large-capitalisation companies (for example, those exceeding NOK 200 million in the Vestre and Wikheim study) seeks to mitigate liquidity risk. However, this approach may yield lower returns compared to studies encompassing the broader market.

Discrepancies in the results that have been reported may also be attributable to divergent approaches to systematic errors, specifically look-ahead bias and survivorship bias. Look-ahead bias, which is an outcome arising from the utilisation of data that was not publicly accessible at the time of portfolio formation (for instance, delays in the dissemination of financial statements), results in a systematic overstatement of historical results. Research employing point-in-time databases or incorporating deliberate time delays within the company selection procedure consistently demonstrates reduced yet more dependable returns. Likewise, the exclusion of companies that have experienced bankruptcy or delisting (survivorship bias) can result in a misleadingly optimistic representation of the strategy's efficacy.

The most significant discrepancy between the results of theoretical models and the realities of market behaviour can be attributed to transaction costs and trading friction, which are often not taken into account in academic historical tests. As demonstrated by Vestre and Wikheim (2022), following the incorporation of transaction costs (i.e. the bid-ask spread and commissions), the alpha of the strategy attains statistical significance solely at the $p < 0.1$ level. This finding lends support to the notion that the realisation of risk-adjusted excess returns may be impractical under actual market conditions. As explicitly stated by the aforementioned authors, "the seemingly high returns from historically tested strategies often disappear in the real world" after costs are taken into account. This finding is consistent with Greenblatt's warnings that strategies with high trading frequency or involving illiquid assets may not outperform the market after transaction costs

are taken into account. Davydov et al. (2016) employ a conservative transaction cost assumption of 0.5%, thereby enabling a more realistic evaluation of the net effectiveness of the strategy.

Perhaps the single most important insight emerging from this literature review is that the specific ROC + EY combination proposed by Greenblatt is not necessarily optimal. The study by Blackburn and Cakici (2017) represents the most direct and compelling challenge to the original thesis. Examining 23 developed markets over the 1991–2016 period, the authors document that the canonical Magic Formula generates no statistically significant excess returns globally. Only after replacing EBIT with gross profit – a cleaner, less manipulable profitability metric – does the strategy produce consistent, economically meaningful, and statistically robust outperformance across virtually all markets examined. This finding fundamentally shifts the interpretation of the Magic Formula's success: the value of combining a quality signal with a valuation signal is not in question, but the particular operationalisation of the quality dimension appears far more critical than Greenblatt originally suggested. In essence, the strategy's effectiveness hinges less on the conceptual marriage of 'good' and 'cheap' companies and more on the robustness and accounting-distortion resistance of the chosen quality metric.

Furthermore, the Finnish evidence presented by Davydov et al. (2016) casts serious doubt on the indispensability of the two-factor Magic Formula. As previously noted, a pure valuation strategy relying exclusively on the EBIT/EV (earnings yield) metric generated higher risk-adjusted returns than the complete Greenblatt specification over the same 1991–2013 period. When combined with findings from Silva et al. (2020) – demonstrating that the Piotroski F-score (Piotroski, 2000) frequently matches or exceeds the performance of the full Magic Formula – a clear pattern emerges: Greenblatt's approach, while demonstrably effective in many settings, is ultimately one of several viable value-investing frameworks rather than the uniquely 'magical' solution originally portrayed.

The Magic Formula's persistent ability to generate statistically and economically significant excess returns across a wide array of markets and sample periods constitutes compelling evidence against both the strong-form and semi-strong-form versions of the Efficient Market Hypothesis (EMH). Under fully efficient markets, a simple, publicly disclosed mechanical strategy relying solely on historical accounting and price data should not be capable of systematically producing risk-adjusted outperformance (Oppenheimer & Schlarbaum, 1981). The efficacy of the Magic Formula thus contradicts the Efficient Market Hypothesis, which posits that asset prices fully reflect available information, thereby rendering it impossible to systematically achieve above-average returns without incurring additional risk (Malkiel, 2003).

In the existing literature on this topic, the efficacy of Greenblatt's strategy is predominantly elucidated through the lens of behavioural finance, wherein the

Magic Formula operates as a behavioural arbitrage strategy. The theory posits that it capitalises on systematic cognitive errors made by investors and so-called limits to arbitrage, which allow price inefficiencies to persist for a protracted period (Barberis & Thaler, 2002).

This strategy is predicated on the exploitation of two fundamental psychological tendencies: namely, overreaction and extrapolation error.

1. The initial phenomenon, as documented by De Bondt and Thaler (1985), among others, pertains to investors exhibiting an exaggerated response to negative short-term news. This leads to a temporary undervaluation of companies that are fundamentally sound. Subsequently, profitability enables the identification of such opportunities (Wutkie, 2020).
2. The second mechanism is that of the extrapolation error, as described by Lakonishok et al. (1994). According to Radke (2023), investors have a tendency to naively extrapolate historical growth rates of “growth companies” (glamour stocks) far into the future, resulting in their overvaluation and concomitant undervaluation of value companies.

Greenblatt (2006) developed a formulaic approach to investing that aims to avoid the pitfalls of emotional herding and the acquisition of overvalued assets. This approach seeks to impose a degree of investment discipline that can be challenging for a discretionary investor to uphold when confronted with market pressures.

Greenblatt’s Magic Formula can also be considered within the framework of contemporary factor investing. It is an illustration of a multi-factor strategy that combines exposure to the Value and Quality factors. It is evident that the strategy in question bears a resemblance to classic value strategies, as evidenced by its similarity to the high Book-to-Market ratio in the Fama and French model. However, Greenblatt contends that Earnings Yield offers a more precise estimation of the actual rate of return for the owner when compared to conventional P/E or P/B ratios (Blackburn & Cakici, 2017). A distinctive characteristic of the Magic Formula is its capacity to consider the quality factor through the return on invested capital (ROIC) ratio. This enables the differentiation of inexpensive yet robust companies from the so-called value traps, which are companies that appear inexpensive but are inherently unstable. As indicated by the findings of recent research, this component exhibits a consistent alignment with the profitability premium as elucidated by Novy-Marx (2013). The latter theorist demonstrated that companies demonstrating profitability engender higher returns.

Multivariate regression analyses (e.g. Fama-French-Carhart) conducted on global markets indicate that the Magic Formula ranking possesses distinctive explanatory power that cannot be wholly ascribed to standard risk factors such as company size (SMB), value (HML) or momentum (WML) (Blackburn & Cakici, 2017). Importantly, this strategy frequently exhibits a negative correlation with the mo-

mentum factor, operating as a contrarian approach – purchasing assets that have recently exhibited substandard performance (so-called ‘losers’) in anticipation of their mean reversion (de Paula, 2016). The combination of the quality factor, denoted by the return on invested capital (ROIC), and the value factor, denoted by the enterprise value to earnings yield (EY), of the Magic Formula serves to mitigate the systematic risk that is characteristic of pure value strategies. This combination offers a return profile that is uncorrelated with simple market risk, also known as beta (Blackburn & Cakici, 2017).

Summary and conclusions

The comprehensive literature review conducted in this study yields several key conclusions regarding the effectiveness and practical applicability of Greenblatt's Magic Formula across international markets.

Greenblatt's Magic Formula emerges as a robust and extensively validated value-investing strategy that, across the majority of examined markets and sample periods, consistently delivers excess returns relative to broad market benchmarks – frequently manifesting as statistically and economically significant positive alpha after risk adjustment. Empirical evidence from highly diverse markets, including the United States, the Nordic region, Brazil and Hong Kong, repeatedly demonstrates the strategy's ability to identify firms capable of generating substantial outperformance over a typical one-year holding period.

Nevertheless, the effectiveness of Greenblatt's Magic Formula is far from unconditional. Its performance is materially moderated by several well-documented factors:

1. Transaction costs represent the single most important practical constraint. The most rigorous studies (e.g. Vestre & Wikheim, 2022) demonstrate that the erosive impact of trading frictions – driven by the strategy's approximately 100% annual turnover – can completely eliminate statistically (and economically) significant alpha.
2. Although the strategy benefits from a modest size tilt, the small-firm premium is not its primary driver. Compelling evidence shows robust outperformance even in large-cap, highly liquid universes when value-weighted portfolios are employed, thereby refuting overly simplistic size-based explanations (Blackburn & Cakici, 2017).
3. Performance exhibits strong regime dependence, with the highest excess returns typically realised during periods of broad market undervaluation or post-

crisis recovery phases, and markedly weaker results during late-stage bull markets dominated by growth stocks (Alberg & Seckler, 2015).

4. The original ROC + EY specification does not appear globally robust. Multiple studies find that simpler single-factor valuation strategies (especially pure EBIT/EV) or modified quality metrics (most notably gross profit in place of EBIT) frequently dominate the canonical two-factor version, casting doubt on the purported unique superiority of Greenblatt's exact indicator combination (Blackburn & Cakici, 2017; Davydov et al., 2016).

In conclusion, Greenblatt's Magic Formula is not a universally 'magical' solution that guarantees superior performance under all market conditions. It is, however, a robust, empirically supported value-investing framework that has repeatedly demonstrated the ability to generate excess returns across a wide range of international markets. Its principal strengths lie in its simplicity, full transparency, and – most importantly – the rigorous discipline it imposes on the investment process, thereby shielding investors from common emotional and cognitive biases. At the same time, the strategy's effectiveness is highly contingent on transaction costs, market regimes, firm-size universes and the precise specification of its quality and valuation metrics. When these factors are not carefully controlled, the strategy's apparent outperformance can diminish substantially or even disappear entirely.

In the light of these findings, three particularly promising avenues for future research emerge:

1. Examination of the Magic Formula's performance in the post-2020 environment, encompassing the COVID-19 pandemic, severe supply-chain disruptions, record-high inflation and the subsequent aggressive monetary tightening – conditions that represent a markedly different market regime from those prevailing in most earlier studies.
2. Further exploration of modified versions of the strategy, especially those replacing EBIT with cash-flow-based measures or gross profit, which have already shown greater global robustness and resistance to accounting distortions (Blackburn & Cakici, 2017; Vestre & Wikheim, 2022).
3. Investigation of hybrid strategies that combine the Magic Formula with complementary factors (most notably momentum or low-volatility screens) to determine whether such combinations can deliver more consistent risk-adjusted returns across diverse market cycles.

Ultimately, the enduring contribution of Greenblatt's Magic Formula lies not in its claim to infallibility, but in providing compelling evidence that systematic, quantitative value-investing strategies – when properly implemented – continue to exploit persistent market inefficiencies more than two decades after the strategy was first made public.

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To know or not to know? How societal factors and education shape the financial awareness and knowledge of students

 Maksymilian Czauderna¹

Abstract

This paper explores the impact of societal factors and various forms of education on shaping students' financial awareness and knowledge levels. In the modern world, where access to various instruments and, consequently, risks is increasing, along with the economic challenges that youth will face in the future, it is crucial to assess whether students' understanding of relevant concepts is sufficient. A statistical study analysing different correlations among various factors, based on a survey of 336 students aged 18–24, provides a comprehensive understanding of how financial knowledge and awareness are shaped and developed. The findings reveal that individual and social learning, as well as effective utilisation of accessible resources, are among the key drivers influencing the subject. The study also suggests potential directions for policymakers, highlighting the importance of practical involvement and real-time risk exposure as measures that could significantly enhance students' financial knowledge and awareness.

Keywords

- financial literacy
- financial behaviour
- social learning theory
- self-directed learning
- youth financial socialisation

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Introduction

In a world where teenagers can invest in cryptocurrencies before they understand compound interest, the gap between financial exposure and literacy is widening rapidly. Despite increasing access to financial apps and online resources, fewer than one in three young adults worldwide demonstrate basic financial skills (OECD, 2016, 2020). Additionally, disconnection exposes not just a failure of formal education but also a broader societal shortfall in preparing youth for real-world financial decisions. Financial attitudes are not developed solely in classrooms – they are shaped through family conversations, peer influences and online environments (Lusardi & Mitchell, 2014). Understanding how and from whom young people learn about money is now more urgent than ever. This paper explores these social dimensions to reveal what drives or hinders financial awareness among students aged 18–24 in Poland.

Zeiser et al. (2024) provide a comprehensive overview of what is meant by financial knowledge or awareness. They cite Bacon (1596) who highlighted the importance of controlling expenses and saving, while Benjamin Franklin (1736) stated that a key element on the path to wealth is recognising that credit generates additional costs. As an overarching concept, these authors emphasise proper handling of personal finances, which this study operationalises as a composite construct of objective financial literacy (e.g. risk comprehension, instrument knowledge per OECD/INFE standards) and subjective perceptions (e.g. self-assessed confidence). Throughout the paper, “financial awareness and knowledge” consistently refers to this integrated understanding of sustainable personal finance management, measured via Likert self-reports and behavioural proxies (detailed in Methodology), aligning with Financial Socialisation Theory (Gudmunson & Danes, 2011).

In the United States, 23.1% of adolescents aged 15–18 lack basic financial skills, while globally, only 27% comprehend simple financial concepts. Such low levels of financial literacy highlight a widespread lack of understanding of fundamental personal finance. Since the age at which financial discussions begin influences later financial behaviour (Abdul Ghafoor & Akhtar, 2024), the absence of early financial education constitutes a serious social issue that leads to poor financial decision-making.

Disparities in saving ability across Europe are wide. In 2020, 80.2% of Swedes could save monthly, compared with only 13.3% in Bulgaria (Eurostat, 2020). Yet, assuming that economic development precedes financial literacy is simplistic. In the United States, approximately 78% of NFL players reportedly experience financial distress or bankruptcy within two years of retirement, even though many originate from middle-income families (Torre, 2009). This suggests that wealth alone may not guarantee financial competence.

The study aims to examine the impact of social factors on the financial literacy and awareness of students aged 18–24. Its main objectives are:

RQ1: What are the key factors shaping young people's financial awareness?

RQ2: What steps can enhance young people's financial literacy?

To achieve these goals, a mixed-methods approach was used. The empirical part involves survey data from Polish university students aged 18–24. It examines their knowledge of financial instruments, investment behaviour, attitudes to personal finance, as well as main sources of financial information.

The structure of the paper is as follows: Section 1 reviews the existing literature on youth financial awareness, Section 2 presents the research methods, while Section 3 outlines the findings. The following section presents these results in relation to prior studies and new insights. Finally, the last section concludes by summarising the key findings and offering recommendations for policymakers.

1. Literature review

Understanding why financial literacy is lower in developing countries requires several key theories. Becker's Human Capital Theory (Becker, 1993) is central, complemented by Bandura's Social Learning Theory (Bandura, 1977), highlighting family and peer influence. Behavioural Economics reveals that even literate individuals face cognitive biases like overconfidence (Kahneman & Tversky, 1979). Financial Socialisation Theory stresses that family financial discussions build crucial competence (Gudmunson & Danes, 2011). These frameworks help explore education, family and social impacts on financial literacy in those aged 18–24.

Recent research reveals gaps in youth financial awareness, focusing mostly on adults (Mancone et al., 2024). Young adults face more financial challenges than prior generations (Muat et al., 2024), yet societal norms often silence finance talks (Schnurr, 2022). College years bring heightened financial duties without enough education or awareness (Rodríguez-Correa et al., 2025).

Many US youth and adults fail basic financial knowledge tests (Lusardi & Mitchell, 2014), with only 10% attaining top proficiency (NEFE, 2017), indicating widespread deficits even in advanced economies. Over half do not save for retirement (Lusardi et al., 2009), linking low literacy to low savings (Muat et al., 2024) and poor financial outcomes (Lusardi & Mitchell, 2014). This jeopardises stability in crises.

Even developed countries report poor student financial behaviours. Cannistra et al. (2022) found Italians and Slovaks showed the weakest behaviours, Dutch

students saved least, while Estonians performed best, likely due to fintech use. Estonia also leads Europe in digital learning (Centre for European Policy Studies, 2020). Despite technology growth, knowledge gaps remain (Tripathi & Jariwala, 2025).

A meta-analysis of 76 studies with 160,000+ participants shows that education improves knowledge most in budgeting and saving but less in complex behaviours; effects persist over time (FINRA, 2022). Risk and return remain poorly grasped even by university students (Lusardi & Mitchell, 2014). Many programs fail to build true awareness or real-world skills (Amagir et al., 2018), as students struggle to apply concepts practically (Agyekum, 2024).

Parental influence is often understated, despite evidence suggesting it may outweigh socioeconomic factors (Abdul Ghafoor & Akhtar, 2024). Family discussions financial matters enhance saving and investing skills, thereby forming a foundation of financial education (Agnew & Sotardi, 2025). Moreover, early financial literacy contributes to the development of lifelong financial competence (Mancone et al., 2024). In this context, the influence of the family can be considered comparable in importance to formal education (Solon et al., 1987).

Perceptions of wealth vary significantly across social classes. Financial illiteracy is disproportionately concentrated among minority groups and individuals from low-education households (Lusardi et al., 2009). In the United States, low-income families often perceive wealth as unattainable and exclusive (Schnurr, 2022). Attitudes toward money also play a critical role: status-oriented values tend to undermine sound financial behaviour, whereas frugality has a protective effect (de Almeida et al., 2021). Importantly, financial literacy helps overcome dependence on poverty and support upward mobility (Wang et al., 2022). At the same time, evidence suggests that wealthier youth tend to be more materialistic (Gołąb & Będzik, 2020). Educational disparities further reinforce these inequalities – for example, data from the United Kingdom indicate that disadvantaged 15-year-olds demonstrate financial skills comparable to those of more affluent 11-year-olds (Anders et al., 2022). Notably, children develop class-based financial stereotypes at an early age (Elenbaas & Killen, 2018).

Findings on gender and age differences in financial literacy are mixed. While Kokkizil et. al. (2017) report lower levels of financial literacy among women and younger adults, other studies find no significant gender differences, as evidenced in Ghana and Hungary (Agyekum, 2024; Berlinger et al., 2025). Cziriak et al. (2024) suggest that observed gender disparities may stem more from differences in self-confidence than from actual knowledge. In the United States, some research indicates that women may exhibit higher levels of overconfidence, which can translate into greater risk-taking, although financial literacy appears to mitigate this effect (Nguyen et al., 2024). Conversely, evidence from Italy reveals a persistent gender gap disadvantaging girls, particularly across regions (Bottazzi & Lusardi, 2020).

Age-related patterns are more consistent. Younger individuals tend to overestimate their financial knowledge (Fan & Henager, 2025; Sebastião et al., 2024), and limited experience can negatively affect their financial decision-making (Stoddard & Urban, 2018). In contrast, older individuals generally achieve higher levels of financial literacy (Sims et al., 2020). Overall, the variation in findings highlights the need for further research in this area.

In sum, youth financial literacy reflects complex interactions of education, social context, family influence and behaviour. Current educational gaps and social drivers vary among different societies, but the impact of either well-conducted financial education or a lack of it may be described as similar. A consensus exists on the importance of financial education, social learning and the shaping of positive habits. The absence of these elements has been repeatedly shown to result in misunderstandings of basic concepts, poor decisions and an overall lack of financial well-being. Inherently shaped habits often outweigh the direct impact of education itself, providing an insightful foundation for a broader analysis of the topic. This underscores the importance of societal factors, which can be more influential than state-provided education and conventional learning methods.

2. Methodology

The research aimed to evaluate the level of financial awareness among Polish university students by examining their financial behaviours, knowledge, confidence and perceptions of financial education. The study addressed two research questions:

RQ1: What are the key factors shaping young people's financial awareness?

RQ2: What steps can enhance young people's financial literacy?

A mixed-methods approach was employed (see Table 1), combining quantitative survey data with qualitative open-ended responses analysed descriptively.

The instrument employed seven 5-point Likert-scale items, eight binary or ternary items, five multiple-response items, two frequency scales and one optional open-ended question covering six thematic domains. This design enabled a comprehensive assessment of RQ1 while maintaining a manageable respondent burden of approximately 10–15 minutes.

Table 1. Study design, timeline and methods leveraged

Phase / element	Description
Pilot study	Conducted in November 2024 and March 2025 among 59 students to test clarity and structure.
Main survey	October 2025 with 336 valid responses from diverse Polish universities.
Method	Mixed methods: Quantitative survey (Google Forms) and qualitative open answers.
Key variables	Financial awareness/knowledge (Introduction definition: objective indicators [investment ownership, IKE/IKZE familiarity]; subjective measures [Likert-scale knowledge/confidence, 1–5]), investment behaviour, saving goals, information sources, confidence.
Ethics	GDPR-compliant, voluntary, anonymous.

Source: author's own work.

The study employed a mixed-methods approach using a standardised on-line questionnaire (Google Forms, twenty-three items across six thematic sections: Financial Perception and Motivation; Investment Experience; Risk and Understanding; Local Accounts; Education Habits; and one open-ended question). Prior to pilot testing, the instrument underwent comprehensive content validation by a panel of three experts – two corporate finance specialists with practical and academic backgrounds and one university professor in personal finance – selected according to the expert-judges competence method. Over a two-week review period, each expert independently assessed the instrument for conceptual alignment, clarity, relevance, accessibility and structural coherence. Feedback was gathered individually, documented by the author, and synthesised to ensure objectivity. The experts unanimously recommended two refinements: making the open-ended question optional to reduce respondent burden, and converting descriptive skill-related items into five-point Likert scales to improve measurability and respondent ease. Every item met the experts' adequacy criteria, confirming content validity.

Feedback collected during the pilot phase prompted minor rephrasing of selected items in the main survey; however, full psychometric validation, including the calculation of Cronbach's α , was not conducted. Financial awareness was operationalised using mean scores derived from Likert-scale items capturing self-assessed knowledge and confidence in financial risk and strategy. The independent variables in RQ1 included self-education, investment ownership and regularity, goal achievement, and reliance on family as a source of financial information.

Non-random sampling ($n = 336$) employed a snowball technique combined with purposive recruitment to maintain diversity across academic programmes and geographic areas. The analysis was exploratory in nature (t -tests, ANOVA and Pearson correlations at a significance level of $\alpha = 0.05$). Given the non-random sampling approach, the results should be interpreted as hypothesis-generating

rather than generalisable to the broader population. Although Cronbach's α was not formally calculated, content validity was rigorously ensured through an extensive expert evaluation process employing the expert-judges competence method.

Data analysis was conducted using Microsoft Excel's Data Analysis ToolPak for descriptives (means, SDs, percentage differences), independent-samples *t*-tests (e.g. self-education vs. knowledge), one-way ANOVA (e.g. goal achievement vs. confidence), and Pearson correlations (e.g. number of sources vs. knowledge, $r = 0.49$, $p < 0.001$), with Cohen's *d* effect sizes (0.22–1.28), with a significance level set at $\alpha = 0.05$. the analyses adopted an exploratory, descriptive focus without regression, power calculations or multivariate modelling; no data cleaning was required as analysed variables were complete. Statistical tests (*t*-tests, ANOVA, Pearson correlations) identified within-sample associations only, not population-level inferences. All analysed variables were complete; however, no testing for normality or statistical power calculation was performed due to Excel ToolPak limitations. Figures 1–6 and Table 2 visualise RQ1 determinants to inform RQ2 recommendations.

Table 2. Questionnaire structure by domain

Domain	Items	Formats	Constructs	Sample Items
Financial Perception and Motivation	4	Likert, ternary, multiple-response	Outlook, motivations	Financial future optimism, learning drivers
Investment Experience	6	Binary, frequency scale, Likert, multiple-response	Ownership, regularity	Investment ownership, investing frequency, instruments known
Risk and Understanding	5	Likert, binary	Risk knowledge, strategy skills	Risk comprehension, strategy design confidence
Local Accounts	2	Binary, Likert	IKE/IKZE awareness	Awareness of IKE/IKZE existence, understanding of accounts' rules
Education Habits	4	Likert, binary, multiple-response, frequency scale	Self-learning patterns, learning experience	Pre-uni education quality; number of sources; frequency of learning
Risk Profile	1	Ternary	Risk awareness	"Do you know your risk profile?" (Yes/No/Not sure)
Open-ended	1	Open-ended free text	RQ2 interventions	University education improvements (≤ 100 words)

Source: author's own work. Post-pilot refinements incorporated expert recommendations.

Participants were limited to active Polish university students aged 18–24, verified via opening filter question: "Are you currently a student at a Polish higher education institution?" (Yes/No; No → end). Facebook groups recruited were restricted to student-only membership. Non-probability convenience and snow-

ball sampling targeted students aged 18–24 across Poland, purposefully engaging students from multiple universities and diverse academic fields to maximise geographic and disciplinary representation. Respondents were explicitly requested to forward the survey to peers from other institutions and programmes, thereby extending reach beyond initial networks and promoting sample diversification. The procedure followed a sequential approach: (1) direct personal Messenger and WhatsApp direct messages to verified students from various universities; (2) peer forwarding requests explicitly requesting distribution to students from different institutions and fields, restricted to “students only”; (3) posts in varied Facebook, Messenger and WhatsApp student groups; (4) in-class announcements at Wroclaw University of Economics and Business (facilitated by professors and the author); (5) emails to seven professors for class-group distribution. All invitations stated survey details: anonymous/voluntary participation, estimated maximum 10–12-minute completion time, restricted to Polish university students only, as well as the study purpose (financial awareness research). This multi-channel approach facilitated participation among students from economics, business, and interdisciplinary programmes across both major and regional universities in Poland. As invitations were not systematically tracked, the response rate could not be calculated. The survey introduction included an eligibility filter (“Polish university students only”), yielding 336 complete and verified responses. No exclusions were necessary, as all respondents confirmed student status and provided complete data for the analysed variables. No demographic data were collected in order to preserve anonymity. The sample structure was therefore inferred from the recruitment process: Wroclaw University of Economics and Business constituted the primary contributor, complemented by substantial diversification through onward distribution to institutions in Warsaw, Kraków and regional universities across multiple academic fields.

Although economics and business programmes were more strongly represented due to the initial recruitment networks, the explicit requests to respondents to forward the survey to peers from different universities and disciplines, combined with distribution across varied Facebook and Messenger student groups, ensured representation from diverse fields beyond economics. This multi-channel recruitment yielded a heterogeneous sample spanning multiple Polish universities (Wroclaw University of Economics and Business primary, systematically diversified via peer forwards to Warsaw, Kraków, and other institutions across Polish big cities) across diverse academic fields (economics/business prominent but meaningfully extended to social sciences, humanities, STEM, and other disciplines through cross-institutional forwarding). The sample primarily reflects high student-density urban centres while capturing students originally from smaller towns and rural regions, thus encompassing varied socio-economic backgrounds despite requiring digital access.

The distribution targeted students enrolled in differentiated undergraduate and graduate programmes across several Polish universities. The link to the survey was shared via private messages upon age verification. All ethical requirements were respected. Participation was voluntary and anonymous, personal data were not collected, and procedures conformed to GDPR (Regulation, 2016).

While the use of non-probability sampling precludes population-level conclusions, the study's recruitment design achieved substantive diversity across key dimensions that enhance ecological validity: representation from multiple universities (Wrocław, Warsaw, Kraków, other Polish big cities, regional), diverse academic fields (with economics and business as primary but extending to social sciences, humanities, STEM and others), varied geographic origins, spanning urban centres as well as smaller and rural regions, and both undergraduate and graduate programmes. These characteristics position the findings as internally valid and applicable to digitally connected Polish university students with similar profiles, providing a strong foundation for hypothesis generation and targeted educational interventions.

Key limitations include self-assessment bias, a moderate sample size ($n = 336$), and the use of non-probability sampling. While the convenience/snowball approach precludes probabilistic generalisation to all Polish students, the achieved sample diversity establishes interpretive significance for digitally-connected students across multiple universities, disciplines (economics, humanities, social sciences, STEM and other disciplines) and regions (urban and rural origins), representing a substantial sub-population reached via academic and social media networks (hypothesis-generating only). The absence of demographic data constrains the detailed characterisation of the sample structure. Statistical analyses were exploratory in nature (Excel ToolPak; untested normality/outliers); smaller subgroups risk low statistical power. Moreover, statistical significance ($p < 0.05$) indicates intra-sample patterns only; non-random sampling and absence of demographic controls substantially limit population-level interpretation and practical applicability of effect sizes reported. The instrument relied on single-item knowledge measures without objective validation or internal consistency assessment. Bivariate focus precludes causal inference. Responses from October 2025 occurred amid stable market conditions (no evident volatility bias). These findings are thus hypothesis-generating.

In the Results and discussion section, Figures 1–6 illustrate the determinants of RQ1 through standardised visualisations, including bar charts of Likert-scale means (Figures 1, 2, 4–6) and one radar chart (Figure 3), based on a sample of $n = 336$ and a significance level of $\alpha = 0.05$. The bar charts follow a consistent design: the x-axis presents questionnaire response categories or groups derived from the domains outlined in Table 2, while the y-axis displays mean scores on a 1–5 Likert scale (where 1 = strongly disagree and 5 = strongly agree). Figure 3 (radar chart)

uses radial axes to compare multiple constructs expressed as percentages, ranging from 0% at the centre to 100% at the outer edge. Interpretive captions accompany each figure to clarify the analytical rationale. Error bars are not included in the visualisations; however, standard deviation values are reported in the accompanying tables. Table 3 provides detailed insight into the construction and rationale underlying each figure.

Table 3. Indicators and visualisation specifications for Figures 1–6

Figure	Domain and key comparison	x-axis categories	y-axis primary indicator	Visualisation type and methodological purpose
1	Self-education vs. knowledge scales	“Not engaged in self-education” vs. “Engaged in self-educating”	Mean score (1–5) across knowledge items	Bar chart: Tests RQ1 self-learning pathway (<i>t</i> -test precursor)
2	Investment ownership vs. risk understanding	“Non-investors” vs. “Investment owners”	Mean score (1–5) on risk Likert items	Bar chart: Operationalizes experiential engagement hypothesis (ANOVA precursor)
3	Investing regularity vs. multi-construct awareness	Regular/ Irregular/ All students (Q8 frequency)	% of high responses (1–5 scale): IKE/ IKZE awareness, risk understanding, knowledge, strategy design	Radar chart: 0% center progressing towards 100% outward; 4 radial axes enable multi-construct comparison (correlation precursor)
4	Financial goal achievement vs. confidence	“No”; “No, but working towards it”; “Yes”	Mean score (1–5) on strategy confidence	Bar chart: Tests self-efficacy hypothesis (ANOVA precursor)
5	Number of information sources vs. knowledge	“0 sources”; “1–2 sources”; “3–4 sources”; “5+ sources”	Mean score (1–5) across knowledge items	Bar chart: Visualizes dose-response pattern for source quantity
6	Use of family as an information source vs. knowledge measures	“Not using family” vs. “Using family”	Mean score (1–5) across knowledge items	Bar chart: Tests social learning hypothesis (<i>t</i> -test precursor)

Source: author’s own work.

The study offers an informed overview of student financial literacy in Poland and provides a methodological foundation for future inquiry into youth financial education and related policy development.

3. Results and discussion

Consistent with the definitions outlined in the Introduction and Methodology, the analysis examines financial awareness and knowledge through both objective indicators and subjective measures. This approach enables the identification of key interdependencies shaping the financial awareness of the target group. Financial knowledge is treated as a fundamental underlying factor and analysed as the primary basis for these interrelationships. It is examined in relation to self-education, which serves as a secondary mechanism complementing formal education provided through institutions and structured programmes. All statistical analyses were conducted at a 95% confidence level (significance level $\alpha = 0.05$), ensuring the statistical validity as well as the practical relevance of the observed relationships.

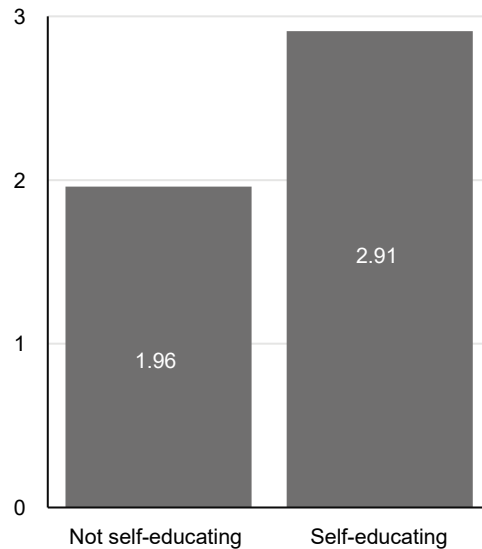


Figure 1. Financial awareness and knowledge levels of self-educating and non-self-educating students

Self-education drastically increases financial awareness and knowledge. Students claiming to learn about finance on their own display a much higher awareness.

Source: author's own survey and analysis.

Students who engage in financial self-education demonstrate 48% higher knowledge when asked to assess it. The average level of knowledge among students who do not educate themselves individually is 1.96, whereas for those who do, it is 2.91. The p -value < 0.001 indicates the statistical significance of this effect, and Cohen's d of 1.28 shows a very strong practical impact of self-education. Standard

deviations of 0.74 for “yes” answers and 0.72 for “no” answers further support the statistical validity of this assessment.

This measurement indicates that self-education should be positioned among the key factors shaping students’ financial awareness. A lack of individually conducted studies leads to a significantly lower knowledge level, which could prove very harmful and dangerous for future financial decisions.

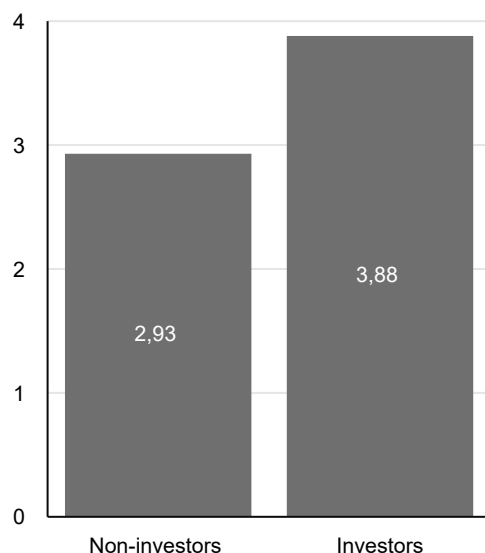


Figure 2. Risk understanding of investment owners and non-investors

Investment ownership shapes risk understanding. Students with investment experience display a visibly stronger risk understanding.

Source: author’s own survey and analysis.

Theoretical knowledge serves as a fundamental basis for future decisions and actions that shape an individual’s financial future. Studying financial concepts and learning about various mechanisms carries no inherent risk. However, without a proper understanding of risk, investing can become hazardous, potentially leading to financial losses.

The study conducted revealed that students who own investments understand investment risk 32% better. This finding highlights the importance of real-time decisions and actions in developing risk comprehension. Experiential engagement equips students with an awareness of their emotions, the risks associated with different instruments, and, crucially, can lead to improved financial decision-making in the future. The p -value < 0.001 confirms the statistical significance of this association, and Cohen’s d of 0.88 indicates a strong practical effect of investment

ownership on risk understanding. Standard deviations of 1.02 for “yes” responses and 1.13 for “no” responses further validate this assessment.

Consequently, investment ownership should be recognised as another key factor shaping financial awareness and understanding of personal finance among young people. Although various factors limit investment ownership in this group, it should be encouraged wherever possible, given its undeniable positive impact on risk comprehension.

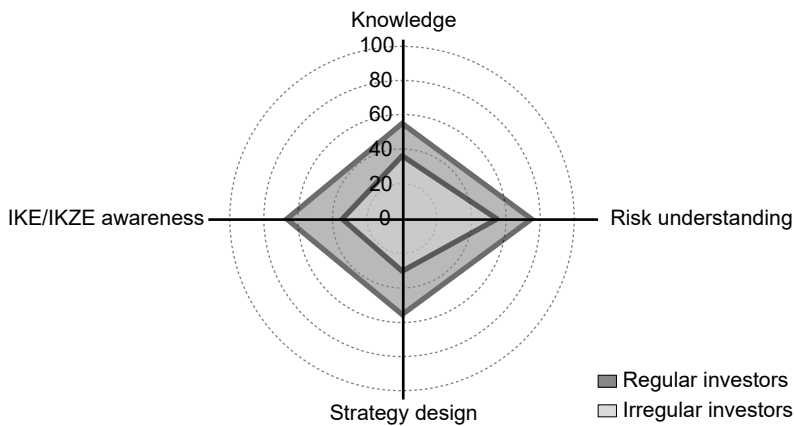


Figure 3. Impact of regular investing on complex factors of financial awareness and knowledge

Investing regularly builds skills, awareness and confidence. Students that invest regularly display a higher overall financial awareness and knowledge.

Source: author's own survey and analysis.

However, it is the regularity of investing that has the strongest impact on complex financial awareness. Another analysis compared responses from students who reported investing regularly against those who invested irregularly. Only students who claimed to invest regularly were included in this study.

Regular investors demonstrated higher levels of financial competence, including 31% higher knowledge, 25% greater risk understanding and a 45% stronger ability to design their own investment strategies. Additionally, a higher proportion of regular investors (by 32.08 percentage points) reported familiarity with IKE and IKZE investment accounts available in Poland. These findings highlight a strong positive influence of consistent investing on all evaluated metrics. Financial awareness is a skill that can be developed through practice, and just as with other skills, regular investing exercises lead to significant progress. For the three quantitative metrics – knowledge, risk understanding and strategy design – the p -value < 0.001 confirms the statistical significance, and Cohen's d of 0.88 indicates a strong prac-

tical effect of regular investing on complex financial awareness. Average standard deviations of 0.96 for “yes” responses and 1.01 for “no” responses further validate the robustness of this assessment.

As indicated by the previous study, ownership of investments improves risk understanding; however, it is consistent investing that drives multifaceted enhancement of complex financial awareness and various skills essential to understanding personal finance.

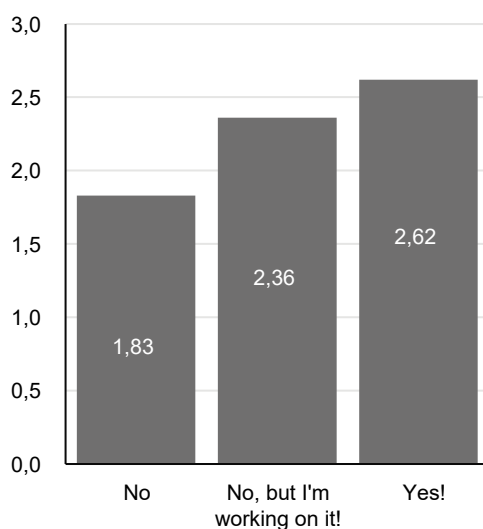


Figure 4. Impact of financial goal achievement on strategy design confidence

Success builds confidence. Students who have achieved a financial goal or are working on it are more confident about their strategy design skills.

Source: author's own survey and analysis.

Previous tests indicated that experiential engagement enhances various financial skills. These findings are supported by a study focusing on a simpler aspect of building personal wealth – saving. Students were asked whether they had achieved any financial goal in their lives, which could be as straightforward as saving a set amount of money. Their responses were then assessed against their financial self-efficacy in designing investment strategies to evaluate how practical experience in pursuing a goal supports self-belief in managing personal finance strategies.

The results indicate that achieving, or even working towards, a financial goal significantly boosts self-efficacy. An ANOVA test yielded an F -statistic of 7.38, underscoring the importance of such efforts in building self-efficacy. Students who had achieved any financial goal reported 43.1% higher financial self-efficacy, supported by a p -value < 0.001 and a Cohen's d of 0.67, reflecting a solid practical

effect. Those who were on the path towards a goal, but had not yet achieved it, demonstrated 28.98% higher efficacy compared to those not pursuing any goal, with a p -value < 0.05 and Cohen's d of 0.50, indicating a meaningful practical impact. It is worth noting that the difference between students who had reached a goal and those still progressing was smaller; students who had achieved a goal showed only 10.9% greater financial self-efficacy. However, with a p -value of 0.15 and a low Cohen's d of 0.22, this difference lacks statistical significance.

This study emphasises the importance of taking initial steps. Even small achievements or clear progress towards a goal, combined with consistent effort, lead to a noticeable increase in investment efficacy. This provides further evidence that the practical application of theoretical knowledge in daily life plays a vital role in shaping the financial awareness of young people.

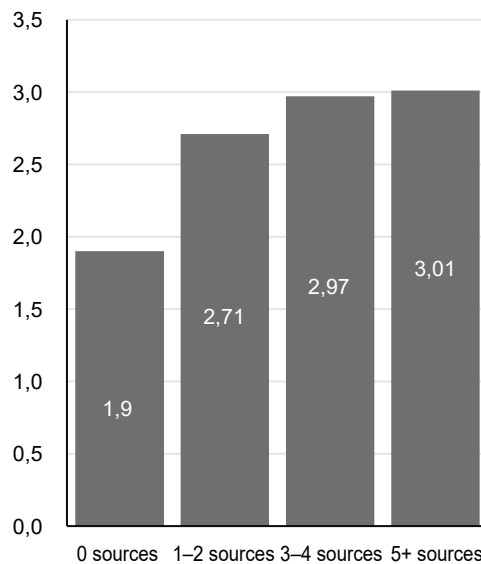


Figure 5. Impact of the number of sources on the level of financial knowledge and awareness

Higher number of sources helps in shaping awareness, though quality remains a key factor. Correlation between number of sources and level of knowledge is visible, but as the number increases, the positive difference diminishes.

Source: author's own survey and analysis.

Figure 5 illustrates diminishing marginal returns in the use of financial information sources. A Pearson correlation ($r = 0.49$, $p < 0.001$) indicates a moderate positive association between the number of sources and financial knowledge. The largest increase is observed with the first additional source (+42.4%), followed by substantially smaller gains for subsequent categories (+9.8% and +1.4%),

suggesting a diminishing returns pattern. Table 4 provides a detailed breakdown of source composition.

Table 4. Composition of sources used by students for financial education

Source	Number of responses	% of total respondents
YouTube channels	182	54.2
Social media	147	43.8
Friends or family	142	42.3
Financial blogs/websites	124	36.9
Books	119	35.4
Podcasts	111	33
Online courses	47	14
Financial advisors	33	9.8
Academic clubs	32	9.5
No sources used	80	23.8

Note: Percentages exceed 100%, as respondents were able to select multiple sources. Additionally, 23.8% of the sample ($n = 80$) reported no engagement in self-education in the preceding filter question.

Source: author's own survey and analysis.

Figure 5 and Table 4 together show that 23.8% of students reported no financial self-education, while among self-educators, a Pearson correlation ($r = 0.49$, $p < 0.001$) indicates a moderate positive relationship between the number of sources and financial knowledge. The first additional source produces a strong +42.4% gain in knowledge, dropping to 9.8% and 1.4% for later sources, which demonstrates diminishing marginal returns.

Table 4 reveals that students strongly prefer accessible digital and personal sources – YouTube (54.2%), social media (43.8%), friends/family (42.3%) – over more reliable professional options like financial advisors (9.8%) and academic clubs (9.5%). This pattern shows that students prioritise convenience over content reliability.

These findings suggest that financial skills are more strongly associated with the quality of information sources and the ability to select them effectively than with the sheer number of sources used. The “finfluencer ecosystem” on TikTok, Instagram and YouTube provides engaging content about investing, saving and debt that lowers entry barriers and builds confidence at first exposure. However, as sources multiply, students face information overload, struggling to process and critically evaluate competing messages, which mirrors the diminishing returns shown in Figure 5.

This ecosystem has mixed effects: it makes financial knowledge more accessible to youth without formal education or family support but also increases risks of

misinformation and oversimplified content designed for engagement rather than accuracy. Educational programs should therefore focus on developing critical evaluation skills for selecting reliable sources – especially with growing AI-generated financial content – rather than simply encouraging more source exposure.

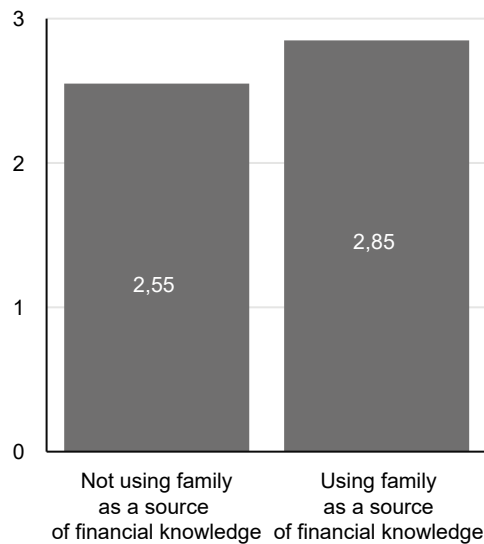


Figure 6. Impact of family-based social learning on respondents' financial knowledge and awareness

Social learning supports knowledge development. Students using their family as a source of knowledge display a higher level of financial awareness.

Source: author's own survey and analysis.

Finally, an exercise evaluating the impact of social learning was conducted. Students who rely on their families as sources of financial knowledge exhibit 12% higher financial knowledge. This underscores the importance of leveraging one's environment in developing financial skills. However, the difference, while positive, is less pronounced compared to previously assessed factors. The p -value < 0.001 indicates the statistical significance of this finding, and Cohen's d of 0.66 demonstrates a noticeable practical effect of family discussions as a source of financial knowledge. These results confirm that social learning positively influences financial awareness and highlight the vital role of family-based discussions in shaping financial literacy. A statistical analysis of all compared metrics provides insight into the relationships between measured factors, their impact on knowledge and awareness, as well as the statistical and practical significance of these effects, presented in the Table 5.

Table 5. Correlation and statistical significance of key factors

Factor	Metric compared	% difference	<i>p</i> -value	Cohen's <i>d</i>	Interpretation
Self-education	Financial knowledge	+48	< 0.001	1.28	Very strong practical effect
Investment ownership	Risk understanding	+32	< 0.001	0.88	Strong effect
Regular investment	Knowledge, strategy, risk understanding	+25–45	< 0.001	0.88 (average)	Strong effect across metrics
Achieving a financial goal vs. none	Confidence in strategy design	+43.1	< 0.001	0.67	Moderate to strong effect
In progress vs. none	Confidence in strategy design	+28.9	< 0.05	0.50	Moderate effect
Achieved vs. in progress	Confidence in strategy design	+10.9	0.15	0.22	Not statistically significant
Number of information sources	Financial knowledge	+42.4% to +1.4%	< 0.001	N/A	Diminishing returns
Family as info source	Financial knowledge	+12%	< 0.001	0.66	Moderate practical impact

Source: author's own survey and analysis.

The findings of this study identify self-education, investment ownership and regularity, success in achieving financial targets, careful selection of knowledge sources and social learning as key factors shaping students' financial awareness. The following section compares these results with the broader scientific consensus to verify the study's outcomes and provide practical recommendations for educational institutions.

Conclusions

The findings of this study not only confirm the existing consensus but also offer important insights into the primary aim of this research: identifying potential directions that educational institutions could implement to enhance financial awareness. Utilising a mixed-methods approach, incorporating Human Capital Theory (Becker, 1993), Social Learning Theory (Bandura, 1977) and Financial Socialisation Theory (Gudmunson & Danes, 2011), the study demonstrates how specific elements of the financial environment contribute to the development of skills, which, collectively, shape financial awareness.

The findings indicate that self-educating students exhibited superior financial knowledge, consistent with the Domains of Learning framework, which asserts that self-directed learners must rely on themselves. Although the effectiveness of self-education depends on multiple factors, this study found not only a higher level of financial knowledge among self-learners but also a lower standard deviation compared to non-self-educated respondents, indicating more consistent knowledge levels. These findings reaffirm Bandura's (1977) self-directed learning theory, which contrasts with a collective and impersonalised approach by highlighting the benefits of individualised learning. This aligns with the findings of Amagir et al. (2018) and Agyekum (2024), who underscore the significance of financial self-education.

Investment owners demonstrated a better understanding of the risks associated with investing. This aligns with Kolb's (1984) experiential learning theory, which posits that active participation in the market enables quicker acquisition of practical skills than relying solely on theoretical learning. Moreover, regular investors not only displayed superior risk understanding but also exhibited greater overall investment knowledge and strategy development skills compared to non-regular investors. These findings correspond with existing literature suggesting that, to acquire solid knowledge and confidence, regular engagement with the subject matter is essential (FINRA, 2022). Therefore, it is crucial for educational programmes to incorporate as much practical experience as possible, which can be achieved through simulations, case studies and other relevant methods.

The findings regarding the achievement of any financial goal support Bandura's (1977) self-efficacy theory, which posits that setting a goal is a crucial step towards fostering effort and maintaining focus. Importantly, it is not necessary to fully achieve a goal to significantly boost confidence; merely beginning the process represents a vital step that leads to a noticeable increase in self-assurance. These findings further emphasise the need to integrate practical financial applications into students' daily lives. This can be facilitated by encouraging students to set financial goals, providing guidance on how to achieve them and assisting in the proper assessment of their progress. It is essential to underscore that even minor financial goals, once set and achieved, can greatly enhance an individual's confidence. When implementing self-education, the use of multiple knowledge sources was shown to enhance respondents' financial knowledge. However, diminishing returns were observed as the number of sources increased from 1–2 up to 5 or more, aligning with Tripathi and Jariwala's (2025) findings. They argue that access to information alone does not guarantee informed and reasonable decision-making. Consequently, developing students' ability to select relevant and reliable information is crucial. This skill, involving verification to ensure safe and applicable data, is increasingly important in resisting the illusions and misinformation prevalent on social media. Given the rapid digital immersion of young-

er generations, fostering critical evaluation of information should be an essential component of education.

In support of Bandura's (1977) social cognitive theory, the study revealed that drawing financial knowledge from relatives has a significant positive impact. Students who reported engaging in such family discussions outperformed those who did not. This finding aligns with the work of Agnew and Sotardi (2025), as well as Abdul Ghafoor and Akhtar (2024), all of whom emphasise the importance of social learning within families and demonstrate the strong influence of family-derived knowledge on subsequent financial decisions. The substantial role of the family environment in shaping financial awareness, observed both in this study and cited literature, suggests a promising avenue for further research aimed at addressing the limited effectiveness of formal educational measures when lacking contextual support. Bandura's assertion that financial socialisation occurs through observing, conversing and critically reflecting on one's participation in financial markets and related contexts could be expanded in formal education, for example, through social campaigns promoting increased frequency of such discussions. As Gudmunson and Danes (2011) underscore, these conversations may have a more powerful impact than the quality of institutional education. Therefore, increasing the frequency of family-based financial discussions could provide a more effective and efficient path to enhancing financial literacy than solely improving centrally provided education.

The results of this research clearly support the multi-dimensional nature of financial literacy and apply this framework specifically to young people. Regular investment activity, the ability to exercise self-control through self-education and goal achievement, alongside the influence of information sources, society and family, are all demonstrated to be important factors shaping overall financial literacy. These findings corroborate the theoretical framework proposed by Lusardi and Mitchell (2014), extending its applicability by validating it within the examined group of Polish respondents.

The accessibility of sources and overall access to education prove insufficient for laying firm foundations for young individuals' financial awareness. This study provides valuable insight indicating that it is primarily self-education, along with a multitude of societal and informational factors, which shape the overall financial knowledge of an individual.

A recurring theme that connects all the findings of this study is the critical importance of practical experience and a deep understanding – not only of the financial instruments themselves but also of individual responses to increased risks or setbacks. An inexperienced investor may make uninformed, panicked decisions during challenging times, whereas those who comprehend market fluctuations, changes in risk and their own emotional reactions are better positioned on the path to wealth building. This aligns with extensive research emphasising that prac-

tical engagement is essential for developing sound financial decision-making skills and confidence, which theoretical knowledge alone cannot fully provide.

Exposure to digital information is now deeply embedded in the daily lives of most individuals. However, it is of utmost importance to understand the risks posed by fake news and misinformation, and the potential complications associated with leveraging multiple sources. A key skill in managing information effectively is the ability to select, filter and critically assess the knowledge obtained.

Given the proven importance of social and family learning, it should draw policymakers' attention that there is significant growth potential to be gained from increasing the number of families that engage in active financial discussions.

Future stages of the research will incorporate multivariate models (e.g. linear regression and structural equation modelling, SEM), subject to data suitability, with the present findings serving as a foundation for further quantitative analysis. Future research with complete demographic data could employ regression modelling for more robust inference. Moreover, future investigations should apply probability sampling, objective financial literacy measures and longitudinal research designs. Specifically, stratified sampling by university type, academic field and geographic region would enhance representativeness and enable more rigorous comparative analysis across student subpopulations. Finally, future research is encouraged to use standardised instruments or to develop and validate custom scales to ensure measurement reliability and comparability across studies.

This paper provides a foundation for key directions in which policymakers could focus their efforts to systematically increase the financial awareness of young individuals, as outlined on the Figure 7.



Figure 7. Key directions for policymakers aiming to foster and enhance financial awareness and knowledge

Source: author's own work.

Firstly, financial education should not focus solely on theoretical approaches but shift its centre of attention towards practical activities. These activities not only involve young participants but also provide experiential engagement, leading to higher financial awareness and knowledge. Secondly, family members and peers should be encouraged to participate in the social contexts of learning, as discussed above. The third essential factor is fostering media literacy, particularly by leveraging popular digital networks to enhance literacy levels. It is also important to provide systematic tools for verification and equip youth with the knowledge to assess the reliability of sources. Lastly, and most importantly, positive financial behaviours should be strongly encouraged. All programmes aiming to educate students on finances should incorporate goal setting, self-efficacy building and progress tracking, with elements that reward achieved milestones. Such solutions are sometimes observed in banking, where achieving savings goals is supported by bonuses provided by institutions. Applying non-material incentives within learning programmes could simulate real-life situations and serve as strong encouragement towards saving and achieving financial goals.

Theory is a key foundation of financial awareness and knowledge. However, theory that is not applied in real-life contexts remains unbeneficial for the learner. Therefore, a variety of practical applications is crucial and should be widely regarded as an essential factor leading to skill improvement within the examined fields.

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The impact of digital transformation on enhancing service quality dimensions in higher education: An applied study at the Faculty of Economics, Setif 1 University

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Abstract

The study aimed to analyse the impact of digital transformation on improving the quality of academic and administrative services at the Faculty of Economic Sciences, Setif 1 University, with a focus on the dimensions of public service quality. The study concluded that digital transformation has a positive effect on service quality, as it facilitated the use of digital systems, reduced the time required for processes and enhanced digital interaction between faculty members and students. Furthermore, organisational culture emerged as the dimension most aligned with digital transformation, reflecting the institution's ability to improve responsiveness and develop both technical and human infrastructure to effectively support service quality.

Keywords

- digital transformation
- public service
- service quality

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Introduction

The new digital economy has changed the international business landscape significantly, with lightning speed tech developments within the information and communication industries. This change has challenged educational organisations to keep up with these advancements through digital transformation at universities and colleges. The use of digital technologies has become a necessity to improve administrative and educational processes, and to streamline interactions between students and faculty members.

Digital transformation encompasses more than technology utilisation; this means creating digital strategies to enhance multiple facets of service quality (e.g. tangibility, reliability, responsiveness and empathy). These aspects contribute significantly towards students' experiences and satisfaction.

Universities, including Setif 1 University in Algeria, have actively engaged in digital transformation initiatives to enhance the quality of their academic and administrative services. In recent years, global developments have accelerated the adoption of e-learning and digital solutions, ensuring the continuity of the educational process. As a result, digital strategies have become an essential and updated approach for most higher education institutions.

Enhancing both educational and administrative services through digital transformation can significantly improve the satisfaction of both staff and students. This study aims to examine the relationship between digital transformation and service quality by analysing the influence of digital transformation on various dimensions of service quality.

Significance of the study

The importance of this study lies in exploring the impact of digital transformation on enhancing the quality of educational and administrative services in universities, particularly amidst rapid technological advancements. It seeks to understand the role of digital transformation in fostering interaction between students and faculty members, thereby enhancing the learning experience by facilitating access to academic content and improving communication methods.

The study evaluates the contribution of digital transformation in strengthening electronic systems for managing educational and administrative processes, which subsequently enhances the quality of academic and administrative services. Furthermore, it offers practical solutions to address challenges faced by Algerian university faculties, contributing to their competitiveness in the global higher education landscape.

Previous studies

Boutarfa & Zedira (2024): This study aimed to develop practical frameworks for implementing both digitalisation and broader digital transformation principles, while also identifying the main digital platforms and programs supporting teaching and learning activities. The study demonstrated that digital technologies play a crucial role in facilitating researchers' work by improving access to information, enabling continuous updates in research methodologies and fostering innovation, ultimately contributing to the enhancement of research quality. Furthermore, the authors addressed the key challenges faced by universities in deploying digitalisation strategies and proposed a set of recommendations aimed at strengthening both teaching practices and scientific research outcomes.

Rosak-Szyrocka et al. (2023): The study investigated the relationship between higher education and digitalisation across European countries, relying on panel data from 31 EU member states over the period 2013–2020. It specifically examined key dimensions of digital development, including internet usage, the integration of digital technologies and the provision of digital public services, as captured by the Digital Economy and Society Index (DESI). The results showed that both the adoption of digital technologies and the effective use of digital public services contribute significantly to improving the management and innovative capacity of higher education systems. Furthermore, the findings showed that the pace and patterns of digital transformation varied considerably between countries over time. The study ultimately emphasised that aligning innovation with digitalisation enhances curricula, supports the deployment of advanced learning technologies, as well as fosters research and creativity within universities, thereby leading to improved student performance.

Aisyah et al. (2023): This study aimed to assess digital transformation in higher education by analysing the key factors influencing its success at Universitas Terbuka. The findings indicated that resources, information systems and organisational culture play a crucial role in enhancing the quality of educational services. The study particularly emphasised the importance of organisational culture in facilitating this transformation.

Verhoef et al. (2021): The purpose of this study was to investigate how digital transformation affects business model innovation in a variety of academic fields. Three phases of digital transformation were distinguished by the study: digitisation, digitalisation and complete digital transformation. It emphasised the growth tactics, resources and skills needed for businesses to successfully execute digital transformation. The results highlighted how digital transformation affects performance measures and calls for particular organisational structures. The study concluded by proposing a comprehensive research agenda to guide future studies on digital transformation and its implications for businesses and markets.

Vial (2019): In this research, 282 works on digital transformation were thoroughly reviewed, and an inductive framework comprising eight essential building blocks was developed. It underlined that companies must modify their value creation strategies while handling organisational and structural issues as a result of the disruptions brought about by digital technologies. The study outlined both the advantages and disadvantages of these procedures and suggested a research agenda that would concentrate on dynamic capabilities and ethical issues as important topics for further study in the fields of digital transformation and strategic information systems.

Research gap

The research gap lies in the lack of comprehensive studies focusing on the impact of digital transformation on the dimensions of service quality within higher education institutions, particularly within faculties of economics. While existing studies have examined digital transformation in other sectors such as telecommunications and banking, there remains a need for an in-depth investigation into its application in university faculties. This includes exploring how digital transformation improves educational, administrative and logistical aspects, understanding its impact on academic performance and student-faculty relationships, as well as developing tailored digital strategies for higher education institutions.

1. Literature review

The existing body of literature highlights digital transformation as a critical driver for enhancing the quality of public services within the higher education sector. Numerous studies underline its role in improving institutional efficiency, strengthening managerial performance and increasing student satisfaction. Scholars have explored the multifaceted nature of digital transformation, examining its effects on educational delivery, administrative and logistical processes, as well as the quality of interactions between academic staff and students. This growing research stream provides valuable insights into the mechanisms through which digital technologies reshape university operations and service provision. The main themes and key findings identified in the literature are outlined below.

1.1. General concepts about digital transformation

1.1.1. Definition of digital transformation

Digital transformation is a change process that involves using digital technologies to develop new business models, improve services and create greater value within an organisation (Li et al., 2023, p. 3). Digital transformation signifies a profound change in the manner services are delivered, utilising technology to improve efficiency and competitive standing. Given the relative recency of this concept, a universally accepted definition remains elusive; however, it is broadly acknowledged as a catalyst for change across various industries by incorporating technology into multiple facets of daily life.

Amin characterises digital transformation as “the transition from a traditional system to a digital system based on information and communication technology across all fields of work” (Amin, 2018, p. 42), emphasising the movement from traditional practices to digital solutions in numerous sectors. Similarly, Belkadi describes digital transformation as “the process of transitioning organisations to a business model that relies on digital technologies for innovating and delivering products and services while creating new value channels” (Belkadi, 2024, p. 694), underscoring its role in service improvement and innovation.

Digital transformation is defined as “a profound transformation in the way a firm leverages digital technologies to develop new digital business models that generate and capture greater value for the firm” (Verhoef et al., 2021, p. 889). This definition emphasises the main purpose of digital transformation, which is to create and capture greater value through digital innovation.

Feroz characterises digital transformation as the application of emerging digital technologies to achieve substantial enhancements in business operations, which may include improving customer experiences, optimising processes or developing innovative business models (Feroz et al., 2021, pp. 1–2). This definition underscores the significance of digital transformation in boosting operational efficiency and elevating customer satisfaction.

Demirkan defines digital transformation as “the profound and accelerating transformation of business activities, processes, competencies, and models to fully leverage the changes and opportunities brought by digital technologies and their impact across society in a strategic and prioritized way” (Demirkan et al., 2016, pp. 14–15). This definition underscores the primary aim of digital transformation, which is to increase efficiency through digital innovation.

The above definitions make it evident that digital transformation revolves around shifting from traditional systems to digital technologies to enhance various operational aspects, from service and product improvement to customer experience and overall performance optimisation.

1.1.2. Importance of digital transformation

Digital transformation is a key driver of economic and social development in the modern era, facilitating streamlined processes and technological advancement across multiple sectors. It enables optimal data utilisation, ensuring timely decision-making and fostering international collaboration. Its impact extends beyond digital enterprises to industries such as healthcare, education and public services, where technological resource investment is essential for maximising benefits. Furthermore, meeting customer and citizen demands necessitates the urgent adoption of digital transformation, highlighting the need for technology integration into institutional processes to ensure sustainable and effective performance (Al Huwaydi & Hassanin, 2022, p. 1048).

1.1.3. Objectives of digital transformation

Digital transformation aims to develop innovative business models that streamline procedures and significantly reduce service delivery time. By replacing traditional, often cumbersome processes with digital solutions, it contributes to increased productivity and improved organisational performance. It also seeks to enhance service efficiency, optimise public expenditure and encourage the adoption of innovative practices, thereby reinforcing public trust and supporting institutional sustainability. Additionally, digital transformation improves the speed, flexibility and accuracy of service delivery while reducing the likelihood of human error. Beyond its operational impact, it fosters a culture of creativity and continuous improvement, ultimately reshaping both organisational practices and societal mindsets (Shedid, 2021, pp. 203–204).

1.1.4. Pillars of digital transformation

Digital transformation is the outcome of four interconnected pillars that collectively shape an organisation's ability to operate effectively in a digital environment. Technology forms the foundation by providing the tools and systems necessary to support digital activities and modernise operational practices. In parallel, data management plays a critical role in converting large volumes of raw data into valuable insights that can guide informed and strategic decision-making. At the same time, the human factor remains essential. Competent and digitally skilled human resources ensure the proper use of technological tools and the effective interpretation of information. Complementing these elements, institutional processes must be continuously refined and adapted to align with digital develop-

ments. This ongoing evolution not only enhances service quality and organisational flexibility but also supports sustainable growth and long-term performance.

1.1.5. Principles of digital transition in administration

Researchers in the field of digital strategy emphasise that the success of digital transition in administration relies on several fundamental principles (Al Mufarji et al., 2016, pp. 27–28):

1. **Establishing an appropriate legislative framework:** Updating laws and regulations to align with modern digital requirements is essential. This includes recognising electronic documents and facilitating their use in official transactions. Additionally, strengthening digital security standards is crucial for protecting data, ensuring information integrity and fostering trust in the digital system, thereby creating a conducive environment for digital transformation.
2. **Developing digital infrastructure:** Enhancing and modernising digital infrastructure is necessary, both in terms of hardware and networks, as well as investing in human capital to keep pace with technological advancements. Moreover, establishing standardised technical frameworks ensures system integration and efficiency, facilitating digital transformation within institutions.
3. **Reengineering administrative processes:** Digital transformation requires redesigning administrative processes to better align with the digital environment. This includes updating management systems using advanced technologies such as artificial intelligence and big data analytics to enhance decision-making efficiency and streamline operations.
4. **Adopting information technology:** Information technology plays a crucial role in digital transformation by improving operational efficiency, enhancing customer experience and fostering innovation in products and services. Additionally, it serves a strategic function in integrating digital processes, thereby strengthening institutional sustainability and competitive advantage.

1.1.6. Dimensions of digital transformation

The literature on digital transformation identifies several key dimensions (Belkadi, 2024, pp. 695–696):

1. **Developing a digital transformation strategy:** This involves formulating a strategic plan that incorporates a clear vision and mission aligned with the institution's overall strategic objectives. The plan should integrate stakeholders and employ innovative approaches to digital planning.

2. **Technical requirements:** Digital transformation necessitates the establishment of an integrated technical infrastructure, including operating systems, specialised hardware, software and storage media. It also requires specialised technical teams to manage this infrastructure efficiently in order to deliver high-quality services.
3. **Organisational culture:** Organisational culture refers to the shared values and concepts among leaders and long-serving employees, which are transferred to newcomers. These values provide the foundation for organisational cohesion and significantly influence employees' behaviour in adopting new technologies.
4. **Procedural requirements:** Digital transformation requires a comprehensive information security strategy to protect data and ensure its quality. This includes implementing strict measures to safeguard privacy and prevent data theft.
5. **Human requirements:** Human resources are a critical element for the success of digital transformation. This necessitates providing well-trained and qualified personnel in areas such as information technology, data analysis and decision-making. Additionally, individuals must possess a strategic vision regarding the importance of digitisation.

1.1.7. Principles of digital transformation in service institutions

1. **Coordination and facilitation of service access:** Enhancing the coordination of services to ensure easier access and enabling beneficiaries to utilise them effectively.
2. **Separation between service providers and recipients:** Establishing a clear distinction between the parties involved in the service while promoting the use of electronic services.

1.2. General concepts of public service

1.2.1. Definition of service

According to Kotler, a service is defined as “an activity or performance that one party can offer to another that is essentially intangible and does not result in the ownership of anything, but satisfies a customer’s need or want” (Kotler & Keller, 2012, p. 404).

The American Marketing Association (AMA) defines it as “a set of activities or benefits associated with the sale of goods, or provided independently, with the purpose of ensuring customer satisfaction” (Azzam et al., 2008, p. 249).

1.2.2. Characteristics of service

Services are distinct from tangible goods and possess specific characteristics, including:

1. **Intangibility:** defined as the characteristic of services whereby the core value consumed is intangible, lying in the change or transformation that occurs in the customer's state or resources as a result of the service, regardless of any accompanying tangible elements. (Moeller, 2010, p. 361).
2. **Inseparability:** Services are typically inseparable from their providers and often require the client's presence (e.g. medical treatment in hospitals). However, some exceptions exist, such as maintenance services performed remotely.
3. **Heterogeneity:** Services are difficult to standardise, as performance varies even within the same institution. For instance, banking services may differ from one branch to another (Ben Obeid, 2022, p. 131).
4. **Perishability:** Services cannot be stored. If not consumed at a certain time, they are lost (e.g. unsold airline tickets represent a permanent loss) (Kotler & Dubois, 2000, p. 466).
5. **Lack of ownership:** Unlike goods, services do not transfer ownership. Clients pay for temporary use or access (e.g. renting a hotel room) without acquiring ownership (El Wafi, 2019, p. 121).

1.2.3. Concept of public service

Public service has been defined in various ways. Among these definitions:

1. "Public service refers to the essential needs required to preserve human life and ensure well-being, which must be provided to the majority of the population. The guiding principle of public service policies should be improving citizens' living standards" (Rahawi & Kasmi, 2017, p. 110).
2. From an administrative law perspective, it is defined as "a technical service provided on a permanent basis by a public institution, requiring managers to uphold the principles of equality, continuity, and adaptability in order to serve the public interest" (Merizq, 2015, p. 14).

From these definitions, it can be inferred that public services are characterised by universality, granting all citizens equal access without discrimination. The state bears the responsibility of ensuring their provision through available legal, technical and financial resources.

1.2.4. Principles of public service

Public services are guided by principles ensuring equality, continuity and adaptability in service delivery. They are designed to remain relevant to social and technological changes while often provided free or at minimal cost. These services promote social solidarity by reducing inequalities and ensuring access for disadvantaged groups.

1.2.5. Characteristics of public service

Key features of public services include:

1. **Public interest:** They encompass activities that serve collective welfare, whether national, administrative or newly emerging due to socio-economic developments.
2. **Public oversight:** The state monitors service delivery to guarantee continuity and equality, with intervention mechanisms in case of dysfunction.
3. **Non-rivalry in consumption:** Public services are accessible to all without reducing others' ability to benefit, ensuring equal access without additional costs (Khalil, 2020, p. 81).
4. **Lack of incentives and clarity of objectives:** Decision-making in the public sector is often influenced by political factors and may lack clear goals or incentive structures, which can hinder performance effectiveness.

1.2.6. Importance of public service

Public services are essential for promoting social solidarity through the provision of basic needs such as education and healthcare, thereby reducing social disparities. They contribute to comprehensive development by ensuring infrastructure, educational opportunities and healthcare services, which collectively support economic growth. Additionally, they foster social and political stability by addressing citizens' needs and strengthening trust in government institutions.

Public services are typically classified into:

1. **Economic services:** e.g. water and electricity.
2. **Social services:** addressing needs the market cannot adequately fulfil. They can also be **free or fee-based**, with some essential services (e.g. digital payment and authentication services) requiring minimal costs (Haddar, 2018, pp. 82–84).

1.3. General concepts of public service quality

1.3.1. Definition of quality

Quality is a multidimensional concept that applies to products, services and processes, aiming to meet or exceed customer expectations and thereby enhance competitiveness and innovation. It represents a set of attributes that reflect positive and acceptable standards as perceived by users (Al Fadl & Al Taie, 2023, p. 20).

The American Federal Quality Institute defines quality as “an applied approach that seeks to meet customer needs and expectations by using quantitative methods to improve processes and services” (Al Karkhi, 2015, pp. 20–21). Accordingly, service quality can be understood as the set of features and characteristics that enable a service to meet or surpass user expectations.

1.3.2. Definition of public service quality

Service quality can be defined as an overall evaluative judgment or attitude formed by consumers toward a service. It appears from the comparison between their prior expectations and their perceptions of the actual performance delivered. In this sense, service quality reflects the extent to which the service meets, exceeds or falls short of what consumers anticipate.

Public service quality refers to the extent to which services meet citizens’ needs and expectations. Quality is defined as “the degree to which a set of inherent characteristics of a product, system or process fulfils requirements” (ISO 9000, 2000, as cited in Hattatash, 2017, p. 453).

Thus, public service quality can be expressed as “the ability of public services to satisfy citizens’ explicit and implicit needs, achieving expected benefits and ensuring fairness and efficiency”.

1.3.3. Characteristics of public service quality

Public service quality emphasises meeting beneficiaries’ expectations through collaboration between providers and recipients (employees and citizens alike). Its key aspects include:

1. **Equality and social justice:** Ensuring universal access regardless of socio-economic or geographic factors.
2. **Sustainable economic growth:** Enhancing living standards and ensuring fair distribution of resources.

3. **Human development:** Providing essential services such as water, energy, health-care, education and transportation.
4. **Good governance:** Characterised by transparency, integrity and the absence of corruption, all in service of the community.

1.3.4. Importance and objectives of public service quality

The importance and objectives of public service quality can be summarised as follows:

1. Expanding the scope of public services across different sectors.
2. Enhancing citizen care by ensuring satisfaction and strengthening loyalty toward public institutions.
3. Measuring satisfaction levels through feedback mechanisms to identify areas of improvement.
4. Improving communication between service providers and recipients to ensure efficiency.
5. Prioritising citizen needs by offering high-quality and responsive services.
6. Promoting continuous improvement through specialised management focused on integration and comprehensiveness in service delivery.

1.3.5. Dimensions of public service quality

Measuring public service quality is inherently challenging, as it largely depends on citizens' perceptions of intangible elements. Among the most widely used frameworks for assessing service quality is the SERVPERF model, which focuses on actual performance as perceived by users. In contrast, the SERVQUAL model emphasises perceived quality, evaluating service against customer expectations (Parasuraman et al., 1985). This model identifies five core dimensions of service quality:

1. **Responsiveness:** The ability of employees to address requests promptly and effectively, adapting to changing conditions and diverse citizen needs. This enhances trust and satisfaction (Munusamy et al., 2010, p. 401).
2. **Reliability:** Refers to the ability to deliver the service accurately and dependably, so that customers can consistently rely on it (Adil et al., 2013, p. 67).
3. **Assurance:** Employees' ability to inspire confidence and trust through professional and attentive conduct, thereby ensuring that citizens feel valued and secure.
4. **Tangibility:** The physical aspects of service provision, including facilities, equipment quality and staff appearance. High standards in these elements positively influence citizens' perceptions.

5. **Empathy:** The degree of personalised care and respect shown to citizens. Empathetic interactions strengthen relationships and build loyalty (Al Mahyaw, 2006, p. 95).

1.4. The relationship between digital transformation and the quality of public service

In recent years, digital transformation has emerged as a fundamental driver in reshaping the functioning of public institutions and the way services are delivered to citizens. By integrating advanced technologies into administrative, logistical and decision-making processes, public organisations aim to enhance efficiency, transparency and responsiveness.

At the same time, the quality of public service has become a central concern, as citizens increasingly expect accessible, reliable and user-centred services. Exploring the relationship between digital transformation and the quality of public service is therefore crucial for understanding how technological innovation contributes to improving service delivery, strengthening trust in government and promoting sustainable development.

1.4.1. The impact of digital transformation on improving public service quality

Digital transformation represents one of the most significant modern mechanisms adopted by governments and public institutions to enhance the quality of services delivered to citizens. The adoption of digital technologies has enabled faster administrative procedures and reduced the time required to complete transactions, thereby increasing efficiency and effectiveness in service delivery (Al Khouri, 2012, pp. 129–130). It also contributes to minimising human errors through the reliance on automated systems, in addition to promoting transparency by allowing real-time tracking of processes and providing channels for grievances and feedback (Bannister & Connolly, 2014, p. 123). Hence, digital transformation is not merely a technical change, but a strategic lever to improve citizen satisfaction and strengthen trust in public institutions.

1.4.2. The role of digital technologies in reinforcing the principles of public service

According to the United Nations Development Programme (UNDP, 2023), inclusive digitalisation enhances equal access to public services, ensuring opportunities for all citizens regardless of socio-economic or geographic differences. Regarding continuity, digital systems ensure uninterrupted service delivery even in times of crisis, such as health pandemics, by enabling remote access. As for adaptability, digital systems allow institutions to respond flexibly to evolving needs and technological changes, thereby offering more efficient and effective services.

1.4.3. Challenges hindering the impact of digitalisation on service quality

Despite its numerous advantages, digital transformation faces several challenges that limit its full impact on public service quality. The first challenge is the weakness of digital infrastructure, particularly the disparity between urban and rural areas in access to communication networks and modern technologies, which hinders the widespread delivery of digital public services (Fitriani et al., 2025). Another significant challenge is the digital divide, which reflects inequalities in individuals' ability to access and effectively use technology, often influenced by factors such as age, educational level, and geographical location (van Dijk, 2020, p. 25). A third challenge is resistance to change within public institutions, as digitalisation requires shifts in mindsets, organisational culture and traditional systems, often leading to resistance at both individual and institutional levels, thereby slowing down the pace of digital transformation and resulting in uneven implementation (Ibrahim et al., 2025, p. 73).

1.4.4. International experiences in enhancing public service quality through digitalisation

Several international experiences have demonstrated the success of digitalisation in improving public service delivery. For example, Estonia has developed a highly advanced e-government model in which 99% of public services are accessible online, reinforcing transparency and boosting trust in government. According to official e-Estonia data, nearly all government services are available digitally, reflecting the country's leadership in digital public service delivery (e-Estonia, n.d.).

Similarly, in South Korea, massive investments in digital infrastructure have positioned the country at the top of the UN e-government rankings, as digitalisation significantly reduced processing times and facilitated access to services (Department of Economic and Social Affairs, 2022, p. 69). These cases confirm that investment in digitalisation produces tangible improvements in public service quality.

1.4.5. Lessons learned and future directions

Several key lessons can be drawn from these experiences. Most importantly, the success of digital transformation in improving public service quality requires a comprehensive strategy that integrates infrastructure development, human resource capacity building and the promotion of a culture of change (Westerman et al., 2014, p. 145).

Future directions point towards smart services that rely on artificial intelligence and big data analytics to provide personalised and proactive services to citizens, thereby enhancing satisfaction levels and improving the efficiency of public spending (OECD, 2025, p. 18). Thus, digital transformation should not be viewed as an end in itself, but rather as a means to achieve high-quality public services rooted in the principles of equality, effectiveness and transparency.

2. Methodology

2.1. Research problem

The study seeks to address the research problem through the following primary questions:

What is the impact of digital transformation on the dimensions of service quality at the Faculty of Economic Sciences, Setif 1 University? In what ways can this transformation enhance aspects such as tangibility, reliability, responsiveness and empathy within the institution?

The following sub-questions arise from the main research inquiry:

- Q1: Does digital transformation positively affect tangibility?
- Q2: Does digital transformation positively affect reliability?
- Q3: Does digital transformation improve responsiveness?
- Q4: Does digital transformation enhance empathy and solidarity?

2.2. Main hypothesis

To address the research problem, we propose the following **main hypothesis**:

H: There is a statistically significant effect at a significance level of ($\alpha = 0.05$) between the requirements for implementing digital transformation and the improvement of service quality dimensions at the Faculty of Economic Sciences, Setif 1 University.

This main hypothesis branches into the following **sub-hypotheses**:

H1: There is a statistically significant relationship at a significance level of ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the tangibility dimension at the Faculty of Economic Sciences, Setif 1 University.

H2: There is a statistically significant relationship at a significance level of ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the reliability dimension at the Faculty of Economic Sciences, Setif 1 University.

H3: There is a statistically significant relationship at a significance level of ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the responsiveness dimension at the Faculty of Economic Sciences, Setif 1 University.

H4: There is a statistically significant relationship at a significance level of ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the empathy and solidarity dimensions at the Faculty of Economic Sciences, Setif 1 University.

2.3. Study objectives

This research aims to achieve the following objectives:

- to assess the extent to which digital transformation dimensions influence the quality of educational and administrative services provided by universities;
- to outline the fundamental theoretical concepts underlying digital transformation and service quality, emphasising their core dimensions.

The study aims to examine the interconnections among different aspects of digital transformation – including the formulation of digital strategies, technical and procedural necessities, human resource considerations and organisational culture – and their impact on enhancing the quality of educational and administrative services.

2.4. Research methodology and instrument

The study adopted the descriptive-analytical approach to examine the fundamental concepts related to the impact of digital transformation on the quality of services in higher education. Additionally, the statistical approach was applied to analyse the data and test the hypotheses using SPSS software.

The data for this study were collected exclusively from the Faculty of Economics at Setif 1 University; therefore, the results should not be generalised to other faculties or the entire university. To collect the data, a questionnaire was employed as the main tool, complemented by direct interviews. The questionnaire was divided into three main sections:

1. The first section addressed personal information such as gender, academic qualification, job position and experience.
2. The second section focused on dimensions of digital transformation and included 25 items.
3. The third section focused on dimensions of service quality and included 16 items.

A five-point Likert scale was adopted in designing the questions. Data were analysed using the arithmetic mean and standard deviation to assess the dimensions.

3. Results and discussion

This section is dedicated to providing an overview of the institution under study, presenting the research methodology and tools, and describing the study sample. Furthermore, statistical analysis has been conducted in order to address the research problem and test the proposed hypotheses.

3.1. Presentation of Setif 1 University as a pioneering model in higher education and digital transformation

Setif 1 University is one of the leading universities in Algeria. Established in 1978, it comprises five main faculties: Technology, Sciences, Natural and Life Sciences, Economics, Commerce and Management Sciences, and Medicine, in addition to three specialised institutes.

Digital transformation at Setif 1 University is a cornerstone in the development of both educational and administrative processes. The university offers several digital platforms, including an e-learning platform to support distance learning, a WebTV platform, and a Virtual Tour platform that allows students to explore the campus remotely. It also provides a Continuing Education platform (Formation Continue) for training programs and the EDX platform, which expands opportunities for on-line learning. These platforms contribute to enhancing the academic experience and facilitating both educational and administrative services.

The Faculty of Economic Sciences, Setif 1 University stands out as a leading institution in Algeria. It offers 45 specialisations in economics, commerce, management sciences, finance and accounting across three academic levels (Bachelor's, Master's and Doctorate). The faculty consists of five departments, supported by 329 professors and 234 staff members, and is equipped with 115 classrooms and lecture halls, 157 offices, as well as three libraries. These resources provide a conducive environment for training qualified professionals and advancing scientific research.

Study population and sample

The Faculty of Economic Sciences, Setif 1 University was selected as the study sample due to its leading role in the university's digital transformation. The faculty comprises four departments: Commerce, Finance and Accounting, Economics as well as Management Sciences, in addition to the Dean's Office.

A purposive sampling method was used to select participants directly involved in administrative and digital transformation activities. The study targeted academic staff with administrative responsibilities and administrative personnel. A total of 60 questionnaires were distributed, of which 44 were returned (response rate = 73.33%). After excluding three incomplete questionnaires, 41 valid responses were retained for analysis (68.33% of distributed questionnaires). This approach ensures that respondents had direct experience with the faculty's digital transformation initiatives, and the results are specific to this faculty only.

3.2. Reliability of the research instrument

To verify the reliability of the study instrument, the Cronbach's Alpha coefficient was calculated to measure internal consistency. The results are presented in Table 1.

Table 1. Cronbach's Alpha for the questionnaire dimensions

Dimension	Title of the dimension	Number of items	Cronbach's Alpha
1	Dimensions of digital transformation	25	0.95
2	Dimensions of service quality	16	0.98
Overall Cronbach's Alpha		0.967	

Source: prepared by the researchers based on SPSS outputs.

Table 1 shows that the questionnaire dimensions have high reliability, with Cronbach's Alpha reaching 0.95 for the digital transformation dimension and 0.98 for the service quality dimension. The overall coefficient for all items of the questionnaire was 0.967, which reflects excellent internal consistency and confirms the reliability of the research instrument. Accordingly, the tool can be confidently relied upon to achieve the intended research outcomes.

3.3. Analytical overview of the study sample characteristics

Table 2 presents the demographic characteristics of the study sample. Females represent 56.1% of the respondents, while males account for 43.9%. In terms of professional experience, 48.8% of participants have more than 10 years of experience, 31.7% have between 5 and 10 years, and 19.5% have less than 5 years. Regarding educational attainment, 39% of the respondents hold a Bachelor's degree, 29.3% a Master's degree, and 13.2% a Doctorate. Concerning job positions, 61% of the sample consists of administrative staff, while 39% are faculty members holding administrative responsibilities.

Table 2. Characteristics of the study sample

Characteristic		Frequency	%
Sex	Male	18	43.9
	Female	23	56.1
Educational level	Bachelor’s Degree	16	39
	Master’s Degree	12	29.3
	Doctorate Degree	13	31.7
Employment position	Faculty with admin. roles	16	39
	Administrative staff	25	61
Experience	Less than 5 years	8	19.5
	5–10 years	13	31.7
	More than 10 years	20	48.8

Source: prepared by the researchers based on SPSS outputs.

3.4. Analysis of the independent variable (dimensions of digital transformation)

The results of the analysis of the respondents' answers regarding the dimensions of digital transformation are presented in Table 3.

Table 3. Responses related to the independent variable

No.	Statements	Mean	Std dev	Relative importance	Degree
1.	The faculty has a clear and well-defined vision and mission for the digital transformation process.	3.78	0.96	2	high
2.	There is alignment and coherence between the digital transformation strategy and the faculty's vision and objectives.	3.87	1.05	1	high
3.	The policies in place contribute to implementing the digital transformation strategy in line with institutional goals.	3.65	1.13	3	high
4.	The faculty periodically evaluates its strategy to ensure alignment with the digital transformation process.	3.51	0.97	4	high
5.	The faculty takes corrective measures to address deviations between actual performance and strategic objectives.	3.02	1.10	5	moderate
Strategic planning dimension		3.57	0.75	high	
6.	The faculty administration encourages greater employee participation in the digital transformation process.	2.65	0.99	5	moderate
7.	The faculty strives to equip its staff with the necessary skills to support digital transformation.	4.14	0.85	1	high
8.	The faculty focuses on training operational staff to enable them to implement digital transformation.	3.90	0.99	3	high
9.	The faculty promotes a culture of development and modernisation in service delivery.	3.19	1.12	4	moderate
10.	The faculty provides programs and mechanisms to spread digital transformation culture and support staff in improving digital skills.	4.00	0.83	2	high
Organisational culture dimension		3.62	0.73	high	
11.	The faculty employs ICT specialists to implement digital transformation projects.	2.97	1.19	5	moderate
12.	The faculty encourages employees to innovate and be creative in the field of digitisation.	3.22	1.15	4	moderate

cont. Table 3

No.	Statements	Mean	Std dev	Relative importance	Degree
13.	The faculty rewards initiatives and contributions that support digital transformation.	3.51	1.02	2	high
14.	The institution ensures that employees receive training and acquire the necessary skills to use modern digital technologies.	3.58	1.18	1	high
15.	The administration plans human resources according to the needs of the digital transformation process.	3.39	1.04	3	moderate
Human resources dimension		3.33	0.93	moderate	
16.	The faculty follows all information security procedures and data protection measures against hacking and cyber theft.	3.73	0.84	2	high
17.	The faculty enforces strict penalties for any security breaches related to data.	3.76	0.76	1	high
18.	The faculty allocates a financial budget to protect data privacy and respect users' and employees' rights.	3.07	1.12	4	moderate
19.	The faculty conducts regular penetration tests to assess the effectiveness of cybersecurity measures.	2.82	1.20	5	moderate
20.	The faculty collaborates with specialised cybersecurity companies to ensure comprehensive data protection.	3.70	0.87	3	high
Procedural requirements dimension		3.47	0.71	high	
21.	The faculty has an advanced technological infrastructure, including modern devices and operating systems.	2.95	1.11	5	moderate
22.	The faculty relies on digital solutions, including storage systems and management software, to ensure smooth operations.	3.31	1.08	4	moderate
23.	The faculty enhances interdepartmental collaboration through an internal online communication system.	3.60	1.11	3	high
24.	The faculty uses an advanced electronic system to receive and process user requests efficiently.	3.87	0.95	1	high
25.	The faculty employs modern technologies to improve the quality and speed of services provided to users.	3.65	1.10	2	high
Technical requirements dimension		3.53	0.90	high	
Overall mean of the independent variable (digital transformation)		3.58	0.69	high	

Source: prepared by the researchers based on SPSS outputs.

Table 3 indicates that digital transformation at the Faculty of Economics, Setif 1, received varying levels of agreement among respondents regarding its different dimensions. The overall mean score for the digital transformation dimensions was 3.58 with a standard deviation of 0.69, reflecting a high level of implementation of digital transformation practices at the faculty. A detailed analysis of each dimension, based on their relative importance, is presented below:

1. **Organisational culture:** The mean score for this dimension reached 3.62, with a standard deviation of 0.73, indicating that the faculty has adopted an advanced organisational culture supportive of digital transformation. This result suggests that the institution fosters innovation and continuous development, motivating staff to embrace modern technologies. It also reflects the faculty's digital ambitions to enhance academic and administrative efficiency in delivering services aligned with the requirements of the digital era.
2. **Strategic planning for digital transformation:** This dimension recorded a mean of 3.57, with a standard deviation of 0.75, showing the faculty's strong commitment to developing a clear and comprehensive digital transformation strategy. This finding indicates that the faculty seeks to establish a structured strategic plan aimed at enhancing digital transformation and aligning institutional activities with its goals. Moreover, this reflects the faculty's alignment with the Ministry of Higher Education's national digitalisation agenda, aiming to integrate technological advancements across academic and administrative processes to improve efficiency and service quality.
3. **Technical requirements:** The mean score for this dimension was 3.53, with a standard deviation of 0.90, showing the faculty's focus on strengthening its technological infrastructure to support digital transformation. Despite the efforts made, there remains a need for further modernisation to ensure comprehensive and effective implementation. This emphasises the importance of adopting cutting-edge technologies and upgrading digital systems to efficiently execute digital transformation strategies.
4. **Procedural requirements:** This dimension ranked second in relative importance, with a mean of 3.47 and a standard deviation of 0.71. This suggests that the faculty prioritises the implementation of integrated and effective data security measures and privacy protection systems. Such practices foster a secure digital environment that builds trust among staff and students, promoting active engagement in digital initiatives. It also highlights the faculty's commitment to adhering to the highest standards of information security in handling digital data.
5. **Human resources:** The mean score for this dimension was 3.33, with a standard deviation of 0.93, ranking it last among the studied dimensions. Nonetheless, this result underscores the critical importance of human capital in supporting digital transformation. The faculty's success largely depends on the competen-

cies of its employees, emphasising the need to strengthen staff skills and provide continuous training to ensure the effective implementation of digital initiatives.

3.5. Analysis of responses for the dependent variable (service quality dimensions)

The results of the analysis of respondents' answers regarding the service quality dimensions are presented in the Table 4.

Table 4. Responses related to the dependent variable (service quality)

No.	Statements	Mean	Std dev	Importance	Degree
26.	The faculty uses modern technologies in the teaching process to enhance the digital learning experience.	3.53	1.02	4	high
27.	The faculty's website is user-friendly and provides efficient electronic services.	3.78	0.82	2	high
28.	The visual design of the electronic systems is appropriate and facilitates navigation, enhancing digital interaction.	4.09	0.76	1	high
29.	The electronic documents and files provided are of high quality and contribute to facilitating digital operations.	3.73	0.89	3	high
Tangibility		3.78	0.64	high	
30.	The faculty is committed to providing its digital services on time with accuracy and efficiency.	3.34	0.88	3	moderate
31.	The electronic service system provides all the operations that faculty members and staff need to perform easily and effectively.	3.82	0.83	1	high
32.	Faculty members and staff can complete all their transactions entirely through the college's electronic system.	3.56	1.00	2	high
33.	Faculty members and staff have full confidence in the accuracy of the information obtained through the college's electronic systems.	3.31	1.03	4	moderate
Reliability		3.54	0.82	high	
34.	The electronic services provided are characterised by a quick response to the needs of the college's affiliates.	3.85	0.85	1	high

cont. Table 4

No.	Statements	Mean	Std dev	Importance	Degree
35.	The college informs its affiliates via electronic messages about the readiness of the concerned service.	3.51	1.07	2	high
36.	The college administration takes immediate corrective actions to address any delays in providing electronic services.	3.10	1.50	4	moderate
37.	The college's affiliates receive prompt responses to their inquiries through the available electronic channels.	3.45	0.97	3	high
Responsiveness		3.49	0.98	high	
38.	Communication with the college's clients through electronic channels is conducted using their preferred language.	3.02	1.10	3	moderate
39.	The college's employees provide personal attention to clients through various digital communication platforms.	2.65	0.99	4	moderate
40.	The college's employees seek to understand clients' problems through electronic tools and propose appropriate solutions.	4.16	0.85	1	high
41.	The college is committed to maintaining the confidentiality of clients' information through electronic systems and applying data protection policies.	3.90	0.99	2	high
Empathy		3.48	0.92	high	
Overall mean of service quality dimension		3.64	0.73	high	

Source: prepared by the researchers based on SPSS outputs.

Table 4 shows that the overall level of service quality is high, with a mean score of 3.64 and a standard deviation of 0.73. These results reflect the faculty's strong commitment to providing high-quality educational and administrative services. A detailed analysis of each dimension according to its relative importance is presented below:

1. **Tangibility:** This dimension recorded a mean score of 3.78 and a standard deviation of 0.64, indicating that the faculty has achieved considerable success in using modern technologies to enhance the digital learning experience. The visual design of electronic systems and the ease of digital interaction contribute to improving the effectiveness of the educational process, demonstrating the faculty's commitment to providing an innovative learning environment aligned with the requirements of the digital era.

2. **Reliability:** With a mean score of 3.54 and a standard deviation of 0.82, this dimension reflects a high level of confidence in the faculty's electronic systems. Respondents expressed trust in the accuracy and credibility of the available information, which highlights the efficiency of the electronic system in facilitating administrative and educational processes, thereby reinforcing reliability and trustworthiness in academic service delivery.
3. **Responsiveness:** This dimension achieved a mean score of 3.49, with a standard deviation of 0.98, indicating that the faculty is actively working to improve response speed to requests through the available electronic channels. Despite certain challenges and limitations, the college remains committed to providing swift and effective solutions to the needs of its affiliates, demonstrating its adaptability to the dynamic demands of the digital environment.
4. **Empathy:** The mean score for this dimension was 3.48, with a standard deviation of 0.92, reflecting the faculty's focus on enhancing credibility and building trust with its clients. The college strives to ensure data confidentiality and protection, fostering a sense of reassurance among users when engaging with electronic systems. Moreover, the personal attention provided through digital communication platforms reflects a collaborative and empathetic approach that prioritises the comfort and satisfaction of students and staff.

3.6. Testing the study hypotheses

3.6.1. Testing the main hypothesis

Hypothesis statement: "There is a statistically significant effect at the significance level ($\alpha = 0.05$) between the requirements for implementing digital transformation and the improvement of service quality dimensions at the Faculty of Economic Sciences, Setif 1 University".

To test this hypothesis, simple linear regression analysis was used, as shown in Table 5.

Table 5. Testing the main hypothesis

Variable	<i>B</i>	<i>r</i>	<i>R</i> ²	<i>t</i> -statistic	<i>p</i> -value
Digital transformation	0.757	0.801	0.64	8.35	0.000

Source: prepared by the researchers based on SPSS outputs.

Table 5 shows that digital transformation plays a significant role in improving service quality at the Faculty of Economic Sciences, Setif 1 University. The independent variable has a direct positive effect on service quality. The t -statistic (8.35) exceeds the critical value (2.021), and the p -value (0.000) is below 0.05, indicating a statistically significant relationship. The coefficient B (0.757) indicates that a one-unit increase in digital transformation leads to a 0.757-unit increase in service quality. Furthermore, $R^2 = 0.64$, meaning that 64% of the variation in service quality is explained by digital transformation. Accordingly, the main hypothesis is accepted.

3.6.2. Testing the sub-hypotheses

Table 6 presents the results of testing the sub-hypotheses that examine the relationship between digital transformation and the dimensions of service quality (tangibility, reliability, responsiveness and empathy) at the Faculty of Economics, Setif 1 University, using a simple regression model.

Table 6. Testing the sub-hypotheses

Variable	B	r	R^2	t -statistic	p -value
Tangibility	0.55	0.69	0.35	4.67	0.000
Reliability	0.95	0.81	0.65	8.57	0.000
Responsiveness	1.09	0.78	0.60	7.69	0.000
Empathy and solidarity	1.10	0.83	0.68	9.24	0.000

Source: prepared by the researchers based on SPSS outputs.

H₁: There is a statistically significant relationship at the significance level ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the tangibility dimension.

The results confirm the existence of a statistically significant relationship between the implementation of digital transformation and the improvement of tangibility. The t -statistic reached 4.67, which is higher than the tabulated value (2.021), thus confirming the validity of the first sub-hypothesis. The correlation coefficient ($r = 0.69$) indicates a strong relationship between digital transformation and the enhancement of tangible service aspects. The coefficient of determination ($R^2 = 0.35$) shows that 35% of the variation in tangibility can be explained by digital transformation.

H₂: There is a statistically significant relationship at the significance level ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the reliability dimension.

The results confirm the presence of a statistically significant relationship between digital transformation and reliability improvement, with a t -statistic of 8.57, exceeding the tabulated value (2.021). The correlation coefficient ($r = 0.81$) reflects a very strong relationship between the two variables, and the coefficient of determination ($R^2 = 0.65$) indicates that 65% of the variations in reliability can be explained by digital transformation. This confirms the validity of the second sub-hypothesis.

H₃: There is a statistically significant relationship at the significance level ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the responsiveness dimension.

The results indicate a statistically significant relationship between digital transformation and the enhancement of responsiveness. The t -statistic of (7.69) exceeds the tabulated value (2.021), confirming the hypothesis. The correlation coefficient ($r = 0.78$) suggests a strong association between digital transformation and responsiveness, while the coefficient of determination ($R^2 = 0.60$) shows that 60% of the changes in responsiveness are explained by digital transformation.

H₄: There is a statistically significant relationship at the significance level ($\alpha = 0.05$) between the implementation of digital transformation and the improvement of the empathy dimension.

The results reveal a statistically significant relationship between digital transformation and the enhancement of empathy and solidarity. The t -statistic (9.24) is greater than the tabulated value (2.021), confirming the hypothesis. The correlation coefficient ($r = 0.83$) indicates a very strong relationship between digital transformation and the improvement of empathy, while the coefficient of determination ($R^2 = 0.68$) means that 68% of the variations in empathy are explained by digital transformation. Therefore, the fourth sub-hypothesis is accepted.

Conclusions and recommendations

The main findings of this study are summarised as follows:

1. **Digital transformation implementation:** The Faculty of Economics, Setif 1, achieved a high overall level of digital transformation (mean = 3.58, SD = 0.69). This reflects strong adoption of digital practices, aligning with Boutarfa and Zedira (2024), who emphasised the role of digital tools in enhancing academic operations and research processes in Algerian universities.
2. **Organisational culture:** Scoring 3.62 (SD = 0.73), this dimension reflects a culture that promotes innovation and continuous improvement. These results are

consistent with Aisyah et al. (2023), who highlighted organisational culture as a key factor facilitating digital transformation and improving service quality in higher education institutions.

3. **Strategic planning for digital transformation:** With a mean of 3.57 (SD = 0.75), the faculty's structured strategic approach ensures alignment of digital initiatives with institutional goals. This finding aligns with Verhoef et al. (2021), who noted that well-defined organisational structures and strategies are essential for successful digital transformation and performance enhancement.
4. **Technical requirements:** Achieving a mean of 3.53 (SD = 0.90), the faculty's focus on robust technological infrastructure supports tangibility and reliability in service delivery. This aligns with Rosak-Szyrocka et al. (2023), who found that integrating digital technologies significantly improves operational efficiency and educational management.
5. **Procedural requirements:** Scoring 3.47 (SD = 0.71), these safeguards ensure data security and privacy, promoting user trust and contributing to empathy and reliability dimensions. Vial (2019) emphasised that effective digital transformation requires managing structural and organisational challenges, consistent with our findings on procedural support.
6. **Human resources:** Despite being the lowest scoring dimension (mean = 3.33, SD = 0.93), human capital is crucial for sustaining transformation. Continuous training and skill development are needed. This finding is in line with Vial (2019) and Aisyah et al. (2023), who stressed the importance of competent staff in implementing digital strategies successfully.
7. **Tangibility (service quality):** The mean score of 3.78 (SD = 0.64) indicates successful integration of modern technologies and user-friendly digital systems. This supports Rosak-Szyrocka et al. (2023) findings on how digital services enhance interaction, learning experiences and student satisfaction.
8. **Reliability:** With a mean of 3.54 (SD = 0.82), this reflects confidence in the accuracy and dependability of electronic services, supporting the link between digital infrastructure and trustworthiness highlighted by Verhoef et al. (2021) as well as Boutarfa and Zedira (2024).
9. **Responsiveness:** Scoring 3.49 (SD = 0.98), responsiveness indicates the faculty's efforts to provide timely solutions. This dimension aligns with prior research on the importance of adaptability and user-centred services in digital environments (Rosak-Szyrocka et al., 2023).
10. **Empathy:** With a mean of 3.48 (SD = 0.92), the faculty demonstrates personalised attention and concern for users' needs. This dimension is consistent with SERVQUAL principles (Adil et al., 2013; Parasuraman et al., 1985) and aligns with findings by Vial (2019) on the importance of human-focused interactions in digital transformation.

To enhance service quality at the Faculty of Economic Sciences, Setif 1 University, and to define digital development priorities aligned with the needs and expectations of its students and staff, the following **recommendations** are proposed:

1. **Enhance digital infrastructure and tangible technologies:** Continuously update and maintain digital platforms and systems to ensure reliable, accessible and sustainable service delivery.
2. **Develop human capital and organisational culture:** Implement ongoing training programs for staff and promote a culture of innovation and active participation in digital transformation initiatives.
3. **Improve responsiveness and electronic service delivery:** Strengthen mechanisms for timely interaction with students and staff, ensuring efficient and effective solutions to all digital service requests.
4. **Promote empathy and user-centred support:** Provide personalised attention through digital channels, safeguarding users' needs and fostering trust and satisfaction among students and staff.
5. **Ensure information security and procedural compliance:** Invest in advanced information security technologies and adopt robust digital governance measures to maintain a safe and sustainable digital environment.

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A theoretical fundamental model of USD/CAD, gold spot and gold futures with interest rates, growth and financialisation

 Mykola Yaremenko¹

Abstract

We develop a three-equation structural model linking the USD/CAD exchange rate, the spot price of gold and gold futures prices. The framework explicitly incorporates real interest rates and financialisation indices for both the United States and Canada, while output gaps influence the exchange rate indirectly through channels including monetary policy expectations, risk appetite and commodity demand. The model accounts for the commodity-currency nature of the Canadian dollar, the opportunity cost of holding gold, and the carry-arbitrage relationship augmented by speculative demand. We derive the model's reduced-form properties and discuss its key theoretical predictions as well as cross-equation feedback mechanisms. Preliminary empirical validation based on cointegration analysis and structural vector autoregression (SVAR) estimation confirms the model's principal theoretical predictions. The analysis highlights the amplification effects arising from the mutual feedback between the exchange rate and gold prices.

Keywords

- exchange rates
- gold
- commodity futures
- financialisation
- commodity currencies
- real interest rates
- USD/CAD
- cost of carry

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Introduction

The relationship between commodity currencies, precious metals and financial markets has become increasingly complex in an era of unconventional monetary policy, cross-border capital flows and financialisation of commodity futures (Cheng & Xiong, 2014; Tang & Xiong, 2012). The Canadian dollar (CAD) is a quintessential commodity currency (Cashin et al., 2002; Chen & Rogoff, 2003), yet its dynamics with gold – a global monetary asset – and the USD/CAD exchange rate cannot be fully captured by simple bivariate correlations. This paper develops a theoretical fundamental model that jointly determines the USD/CAD exchange rate, the spot price of gold and near-term gold futures prices. The model explicitly incorporates real interest rates, economic growth and a measure of financialisation in both the United States and Canada.

Motivation

Traditional exchange rate models (e.g. monetary approach, UIP) often fail to explain short- to medium-term movements in commodity currencies (Engel, 2016; Meese & Rogoff, 1983). Meanwhile, gold pricing models typically focus on US real rates and inflation expectations (Erb & Harvey, 2013; Frankel, 1986, 2008), ignoring the fact that gold is also a major Canadian export and therefore a driver of the CAD. Furthermore, the proliferation of exchange-traded funds (ETFs), algorithmic trading and speculative positioning in futures markets has introduced a “financialisation” channel that can temporarily decouple prices from macroeconomic fundamentals (Basak & Pavlova, 2016; Singleton, 2014). Our model aims to bridge these gaps by embedding gold as both a commodity (affecting Canada’s terms of trade) and a financial asset (sensitive to US real rates and speculative flows).

Endogenous variables

We define three key endogenous variables:

S_t – USD/CAD exchange rate (USD per CAD).

An increase denotes CAD appreciation.

G_t – spot price of gold in USD per fine ounce.

F_t – near-term gold futures price (e.g. 3-month) in USD per ounce.

The choice of F_t as the near-term futures price (defined as the nearest actively traded contract, typically the front-month contract with time to maturity T of approximately 1–3 months) captures the most liquid segment of the futures curve, where carry arbitrage and speculative positioning are most active (Fama & French, 1987; Pindyck, 1994). For empirical implementation, we use a constant maturity of $T = 3$ months (constructed via interpolation between adjacent contract months), which provides a fixed horizon for the cost-of-carry relationship.

Exogenous and policy variables

The model is driven by the following set of exogenous or policy-determined variables, measured for both the US and Canada where relevant:

The ex-ante real interest rate is defined as:

$$\begin{aligned} r_{US,t} &= i_{US,t} - \pi_{US,t}^e \\ r_{CA,t} &= i_{CA,t} - \pi_{CA,t}^e \end{aligned}$$

where $i_{US,t}$ is the nominal yield on a 10-year US Treasury bond (or a 3-month Treasury bill, depending on the horizon), and $\pi_{US,t}^e$ is the expected inflation rate over the corresponding horizon. For empirical implementation:

1. For $i_{US,t}$ – use the 10-year US Treasury constant maturity yield or the 3-month Treasury Inflation-Protected Securities (TIPS) yield.
2. For $\pi_{US,t}^e$ – use the 5-year or 10-year breakeven inflation rate (defined as the difference between nominal and inflation-indexed Treasury yields) or by survey-based measures such as the University of Michigan 5–10 year inflation expectations or Consensus Economics forecasts.
3. The same approach applies to Canada using Government of Canada bond yields and survey-based inflation expectations.

$g_{US,t}, g_{CA,t}$: Output gaps (deviation of actual GDP from potential GDP, measured as a percentage of potential GDP). In empirical implementations where output gap data are not available at the required frequency, these may be proxied by growth momentum measures such as the year-over-year GDP growth rate or industrial production growth. While the baseline model excludes output gaps as direct regressors to maintain parsimony and avoid multicollinearity, they exert influence through three indirect channels: (i) monetary policy expectations affecting future interest rates, (ii) risk appetite and capital flows, and (iii) commodity demand. In an extended specification, the output gap differential $g_{US,t} - g_{CA,t}$ can be included directly.

Φ_t – financialisation index capturing ETF holdings, open interest and speculative positioning (e.g. CFTC COT data).

$Risk_t$ – global risk aversion (e.g. VIX index or geopolitical risk indices).

$P_{oil,t}$ – price of oil in USD/barrel; included because oil is Canada's largest export.

Each variable plays a distinct theoretical role:

1. **Real interest rates** determine the opportunity cost of holding gold (for the US) and the carry trade incentive in USD/CAD (for both countries) (Lustig et al., 2011).
2. **Output gaps** capture cyclical demand pressures that may influence both monetary policy expectations and commodity demand.
3. **Financialisation** aggregates non-fundamental demand from institutional investors, trend-followers and ETF flows (Bhardwaj et al., 2013; Gorton & Rouwenhorst, 2006). This variable can drive gold prices independently of rates, and through the exchange rate, spill over into CAD.
4. **Risk aversion** affects both safe-haven demand for gold (Baur & Lucey, 2010; Baur & McDermott, 2010) and the USD's status as a reserve currency.
5. **Oil price** is a necessary control for CAD because Canada's trade balance is far more sensitive to oil than to gold (Amano & van Norden, 1995).

1. Literature review

Our work builds on three main strands of the literature: (i) commodity-currency exchange rate models, (ii) gold pricing models with a focus on real interest rates and safe-haven properties, and (iii) the theory of storage and financialisation in commodity futures markets. Each strand has made important contributions, yet they have largely developed in parallel, with limited cross-fertilisation between the currency, gold spot and futures dimensions. Our objective is to synthesise these perspectives into a unified framework that captures the simultaneous determination of the USD/CAD exchange rate, the spot price of gold and near-term gold futures, while explicitly accounting for the role of financialisation. To this end, for each literature strand we first summarise the key methodological approaches and empirical findings, then identify the specific gap that our model addresses. This structure allows us to highlight both the incremental extensions and the genuinely novel elements of our proposed framework.

1.1. Commodity currency models

Studies such as Cashin et al. (2002) and Chen and Rogoff (2003) link real exchange rates to commodity prices, establishing the empirical regularity that com-

modity-exporting countries' currencies appreciate when their main export prices rise. Methodologically, these studies typically employ cointegration analysis (Johansen, 1988) or panel data techniques to estimate the long-run relationship between exchange rates and commodity prices. The empirical findings consistently show that commodity prices are significant determinants of real exchange rates for commodity-exporting countries, with oil having a particularly large effect for Canada. Later extensions include Chen et al. (2010), who demonstrate that exchange rates can forecast commodity prices, and Ferraro et al. (2015), who examine the oil-USD/CAD relationship at higher frequencies. Lustig et al. (2011) further show that interest rate differentials and risk premiums are important drivers of currency returns, linking the exchange rate literature to broader asset pricing.

Research gap: existing models in this strand of the literature generally treat commodity prices as exogenous, without allowing for their simultaneous determination within a closed system. Furthermore, to the best of our knowledge, they do not fully incorporate financialisation spillovers within a structural framework.

1.2. Gold pricing models

Frankel (1986, 2008) emphasises real rates and inflation expectations, building on the Dornbusch (1976) overshooting model extended to commodities. The theoretical framework posits that commodity prices adjust to monetary policy shocks more quickly than goods prices, leading to overshooting. Baur and Lucey (2010) and Baur and McDermott (2010) examine safe-haven properties, using quantile regression and dynamic conditional correlation models to identify regimes where gold acts as a hedge (positively correlated with stocks in normal times) or a safe haven (negatively correlated during market turmoil). Erb and Harvey (2013, 2017) provide a comprehensive empirical assessment of gold's long-run fundamentals, finding that the ratio of gold to the US CPI is mean-reverting but with long half-lives, and that gold does not consistently hedge inflation in the short run.

Research gap: to the best of our knowledge, gold is not typically integrated into currency equations for commodity exporters in a fully simultaneous framework, despite its role in Canada's terms of trade. Moreover, the feedback from exchange rates to gold prices (operating through USD) is typically ignored.

1.3. Futures carry arbitrage and financialisation

The theory of storage (Pindyck, 1994, 2001) underpins futures pricing, linking spot and futures prices through the cost of carry, which includes interest rates,

storage costs (c) and a convenience yield (y). Fama and French (1987, 1988) provide early empirical evidence on the forecasting power of futures prices and the role of the basis in predicting spot price movements. Pindyck and Rotemberg (1990) document excess co-movement of commodity prices beyond what fundamentals would predict, suggesting common factors or sentiment-driven dynamics. Gorton and Rouwenhorst (2006) document commodity futures performance, showing that commodity futures returns are positively correlated with inflation and negatively correlated with equity returns, making them attractive for portfolio diversification. Financialisation of commodity markets is analysed by Cheng and Xiong (2014), Tang and Xiong (2012), Singleton (2014), and Basak and Pavlova (2016), who show how index investors and hedge funds affect commodity prices through risk-sharing channels, limits to arbitrage and the rebalancing flows of commodity index funds. These studies demonstrate that financialisation can temporarily decouple commodity prices from traditional supply-demand fundamentals.

Research gap: to the best of our knowledge, existing models do not link futures financialisation premiums to spot exchange rates through explicit cross-market feedback mechanisms, nor do they allow cross-market feedbacks where futures speculation affects the spot exchange rate through the commodity-currency channel.

1.4. Contribution

The primary contribution of this paper is the development of a simultaneous three-equation structural framework that integrates the determination of the USD/CAD exchange rate, the spot price of gold, and gold futures prices within a unified system.

The novel features of the model are as follows:

1. It allows gold to enter the CAD equation as an endogenous variable (rather than exogenous, as in most commodity currency models).
2. It allows the CAD (via USD) to feed back into gold prices through an explicit exchange rate channel.
3. It introduces a financialisation premium in the futures market that is distinct from the cost of carry and directly linked to speculative positioning.

The model also extends existing approaches in several respects:

1. The CAD equation extends the standard commodity currency model (Chen & Rogoff, 2003) by using real rather than nominal interest rates and by treating commodity prices as jointly determined.

2. The gold equation extends the Frankel (1986, 2008) framework by explicitly incorporating financialisation and risk sentiment.
3. The futures equation extends the cost-of-carry model (Pindyck, 1994) by adding a speculative premium, following the insights of Cheng and Xiong (2014) and Singleton (2014).

This closed-loop system generates testable cross-equation restrictions and explains episodes where conventional fundamentals fail (e.g. the 2011 gold rally alongside USD strength).

2. Methodology

In this section, we develop the three structural equations that form the core of our theoretical model. The derivation proceeds step by step, beginning with the USD/CAD exchange rate equation, followed by the gold spot price equation, and concluding with the gold futures equation. Each equation is grounded in economic theory and incorporates the key channels identified in the literature review. We then assemble these equations into a simultaneous system and analyse its properties.

2.1. Equation 1: USD/CAD equilibrium

The Canadian dollar is widely recognised as a commodity currency. Its equilibrium value against the US dollar depends not only on financial factors (interest rates) but also on the real exchange rate implied by the terms of trade. We derive a reduced-form equation that combines uncovered interest parity with a commodity price channel, then augment it with a risk premium and cyclical adjustments.

2.1.1. Theoretical foundation

Let the real exchange rate be defined as

$$Q_t = S_t \frac{P_{US,t}}{P_{CA,t}}$$

where $P_{US,t}$ and $P_{CA,t}$ are price levels.

We employ the concept of a fundamental equilibrium exchange rate (FEER) – the exchange rate consistent with the economy being at full employment and sustainable external position. For a commodity-exporting country, the FEER is primarily determined by the terms of trade.

Following standard practice in the commodity currency literature, we focus on the terms-of-trade channel and abstract from relative productivity, which is typically slow-moving and can be captured by a constant (or a deterministic trend) in the empirical specification. Thus, we model the long-run equilibrium real exchange rate as:

$$Q_t^{LR} = \gamma_0 + \gamma_1 \frac{P_{gold,t}}{P_{US,t}} + \gamma_2 \frac{P_{oil,t}}{P_{US,t}}, \quad \gamma_1, \gamma_2 > 0$$

The constant γ_0 captures, among other things, the long-run level of relative productivity.

The real exchange rate is linked to the nominal exchange rate by:

$$q_t = s_t + p_{US,t} - p_{CA,t}$$

where lowercase letters denote logarithms. Assuming that relative PPP holds for non-commodity goods in the long run ($p_{US,t} - p_{CA,t}$ is stationary), the nominal exchange rate s_t inherits the long-run properties of the real exchange rate. Thus:

$$s_t^{LR} = \gamma_0 + \gamma_1 g_t + \gamma_2 oil_t + \text{stationary terms}$$

where $g_t = \log G_t$ and $oil_t = \log P_{oil,t}$

2.1.2. Real interest rate parity and carry trade

Uncovered interest parity (UIP) states that the expected change in the nominal exchange rate equals the nominal interest differential:

$$E_t[\Delta s_{t+1}] = i_{US,t} - i_{CA,t} - \rho_t$$

where ρ_t is a risk premium.

The transition from nominal to real interest rates is justified by the Fisher equation:

$$i_{US,t} = r_{US,t} + \pi_{US,t}^e$$

and

$$i_{CA,t} = r_{CA,t} + \pi_{CA,t}^e$$

If PPP holds in the long run, the expected inflation differential is related to the expected change in the nominal exchange rate, and the UIP condition can be written in real terms:

$$E_t[\Delta q_{t+1}] = r_{US,t} - r_{CA,t} - \rho_t$$

Solving the model forward under the assumption that the real exchange rate mean-reverts to its long-run commodity-fundamental value q_t^{LR} yields:

$$S_t = \sum_{j=0}^{\infty} \frac{1}{(1+\theta)^j} E_t \left[(i_{US,t+j} - i_{CA,t+j}) - \rho_{t+j} - (q_{t+j}^{LR} - q_t^{LR}) \right] + \text{constant}$$

where θ is the speed of mean reversion.

Assumption 1. The forward solution is obtained under the following assumptions: (i) the real exchange rate q_t is stationary and mean-reverts to its long-run fundamental equilibrium q_t^{LR} ; (ii) the speed of mean reversion θ is constant and positive; (iii) expectations are formed rationally; and (iv) the transversality condition holds, so that explosive solutions are ruled out.

A reduced-form approximation that captures both the UIP carry channel and the commodity terms-of-trade channel is:

$$\ln S_t = \alpha_0 - \alpha_1 (r_{US,t} - r_{CA,t}) + \alpha_2 \ln G_t + \alpha_3 \ln P_{oil,t} + \varepsilon_{S,t} \quad (1)$$

where:

1. $r_{US,t} = i_{US,t} - \pi_{US,t}^e$ and $r_{CA,t} = i_{CA,t} - \pi_{CA,t}^e$ are ex-ante real interest rates. The use of real rather than nominal rates reflects the fact that long-run capital flows respond to real returns, and it also removes the direct inflation effect that would otherwise enter via PPP.
2. G_t is the USD price of gold. For Canada, a rise in G_t means higher export revenue from gold, so the CAD appreciates (S_t increases).
3. $P_{oil,t}$ is the USD price of oil. This is included because oil dominates Canadian trade.

2.1.3. Parameter signs and economic mechanisms

Gold and oil prices enter the exchange rate equation because they are key determinants of Canada's terms of trade and external balance.

Gold is a significant Canadian export, accounting for approximately 5% of mine production and about 3% of total merchandise exports. A rise in the USD price of gold directly improves Canada's terms of trade, increasing export revenues and attracting capital inflows.

Oil is Canada's principal export commodity, accounting for over 20% of total exports and approximately 10% of GDP. Consequently, changes in oil prices exert a first-order effect on Canada's terms of trade and trade balance.

Accordingly:

1. $\alpha_1 > 0$ – a higher US real rate (relative to Canada) attracts capital flows into USD assets, leading to an appreciation of the US dollar and a depreciation of the Canadian dollar.
2. $\alpha_2 > 0$ – as gold is an important Canadian export, an increase in the USD price of gold directly improves the CAD's terms of trade. Estimates reported in the literature (Cashin et al., 2002; Chen & Rogoff, 2003) suggest an elasticity in the range of 0.05–0.10.
3. $\alpha_3 > 0$ – oil has a larger coefficient than gold due to Canada's much higher export share. Indicative estimates (Amano & van Norden, 1995) suggest an elasticity in the range of 0.10–0.20.

2.1.4. Inclusion of output gaps and growth

While not explicitly present in Equation (1), the output gaps $g_{US,t}$ and $g_{CA,t}$ influence the exchange rate through the following channels:

1. **Monetary policy expectations:** Central banks systematically respond to output gaps. A positive US output gap may signal future rate hikes, affecting $r_{US,t}$ with a lag.
2. **Risk appetite and capital flows:** Stronger US growth often boosts global risk appetite, which tends to favour commodity currencies like the CAD.
3. **Commodity demand:** Stronger global growth increases demand for commodities, including gold and oil, which then feeds through to the exchange rate via the commodity price channels.

In an extended version, one could include the output gap differential directly:

$$S_t = \alpha_0 - \alpha_1(r_{US,t} - r_{CA,t}) + \alpha_2 G_t + \alpha_3 P_{oil,t} + \alpha_4(g_{US,t} - g_{CA,t}) + \varepsilon_{S,t}$$

with $\alpha_4 > 0$ if stronger Canadian growth relative to the US appreciates the CAD. However, to maintain parsimony and avoid multicollinearity, we keep the simpler specification.

2.1.5. The error term $\varepsilon_{S,t}$

The term $\varepsilon_{S,t}$ captures short-run deviations from the long-run equilibrium, including central bank intervention, liquidity shocks, temporary mispricing and noise trading.

2.1.6. Relationship to other equations

Equation (1) constitutes the first block of the simultaneous system. The spot price of gold G_t appears on the right-hand side. In turn, the exchange rate S_t influences the spot price of gold G_t through the USD index), because gold is denominated in USD. This interaction gives rise to a feedback mechanism, which is analysed in Section 3.

2.2. Equation 2: spot price of gold

Gold is a unique asset: it pays no coupon or dividend, incurs storage costs, but serves as a store of value, an inflation hedge and a safe haven. Its price is determined globally in US dollars. The equilibrium condition balances the opportunity cost of holding gold against its perceived benefits as a monetary and speculative asset.

2.2.1. Theoretical foundation

Consider an investor choosing between holding gold and investing in a US Treasury bill that offers a real return $r_{US,t}$. In equilibrium, the expected real return on gold must equal the real interest rate, after accounting for the convenience yield and the risk premium. Solving the model forward under the assumption of rational expectations yields:

$$G_t = \beta_0 - \beta_1 r_{US,t} + \beta_2 \pi_{US,t}^e + \beta_3 \Phi_t + \beta_4 Risk_t + \varepsilon_{G,t} \quad (2)$$

with $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$. The term $\pi_{US,t}^e$ captures the inflation-hedging demand.

Assumption 2. The forward solution for gold prices is derived under the assumptions that: (i) gold is an asset that pays no dividend or coupon; (ii) the risk-free real interest rate is the relevant discount rate; (iii) investors form rational expectations with complete information; and (iv) the price of gold does not exhibit explosive dynamics, ensuring that the present value relationship is well-defined.

2.2.2. The role of US real rates and inflation expectations

The coefficient β_1 measures the sensitivity of the gold price to the US real interest rate. A one-percentage-point increase in r_{US} is typically associated with a 5–10% decline in the price of gold in the short run. Inflation expectations $\pi_{US,t}^e$ enter the equation separately from $r_{US,t}$. Empirically, β_2 is often smaller than β_1 because inflation expectations are already partially reflected in r_{US} through the Fisher equation.

2.2.3. Financialisation (Φ_t)

The financialisation index Φ_t is constructed as the first principal component of three normalised series: (i) total gold ETF holdings (in tonnes), (ii) COMEX gold futures open interest (in contracts), and (iii) the CFTC net non-commercial long position (normalised by open interest). This approach follows the methodology of Cheng and Xiong (2014) and Singleton (2014), capturing both the level of institutional participation and the speculative intensity in gold markets. Each component is standardised to zero mean and unit variance before aggregation. The coefficient $\beta_3 > 0$ captures the effect of non-fundamental demand.

2.2.4. Risk sentiment (Risk_{*t*})

Gold is widely regarded as a safe-haven asset. During typical risk-off episodes, gold appreciates as investors seek refuge ($\beta_4 > 0$). However, during extreme liquidity crises, investors sell gold alongside other assets to raise cash, leading to a temporary decline in its price. Consequently, the sign of β_4 is regime-dependent.

2.2.5. The role of economic growth

Economic growth affects gold prices through two channels. First, **commodity demand**: stronger global growth (particularly from the US and emerging economies) increases industrial demand for gold (jewellery, electronics). Second, **monetary policy expectations**: stronger growth may signal future rate hikes, which could lower gold prices through the real rate channel, but this effect is already captured through $r_{US,t}$. The net effect is ambiguous and likely regime-dependent.

2.2.6. Why Canadian real rates do not appear directly

Gold is priced in US dollars and traded globally. Consequently, the opportunity cost of holding gold is determined primarily by the US real interest rate. Canadian real interest rates $r_{CA,t}$ affect gold only indirectly through the exchange rate channel and the strong correlation between US and Canadian real interest rates. Including both variables directly in the gold price equation would introduce multicollinearity without providing additional theoretical insight.

2.2.7. Error term $\varepsilon_{G,t}$

The error term captures temporary supply shocks, high-frequency noise and measurement errors. While some studies find that gold prices and real interest rates are not cointegrated over long samples (Erb & Harvey, 2013), others find evi-

dence of a long-run relationship when allowing for structural breaks. Our model accommodates instabilities through the financialisation and risk terms.

2.2.8. Incorporating exchange rate feedback

Equation (2), in its baseline form, does not include the exchange rate directly. However, as gold is denominated in USD, changes in the USD/CAD exchange rate affect the effective USD price of gold for non-US investors. To capture this mechanism and close the model, Equation (2) is augmented with an explicit exchange rate term:

$$G_t = \beta_0 - \beta_1 r_{US,t} + \beta_2 \pi_{US,t}^e + \beta_3 \Phi_t + \beta_4 Risk_t - \gamma \ln(\text{USD Index}_t) + \varepsilon_{G,t}$$

Since

$$\ln(\text{USD Index}_t) = -\ln S_t + C$$

where C is a constant, Equation (3) can be rewritten as

$$G_t = \beta_0 - \beta_1 r_{US,t} + \beta_2 \pi_{US,t}^e + \beta_3 \Phi_t + \beta_4 Risk_t + \gamma \ln S_t + \varepsilon_{G,t} \quad (3)$$

with $\gamma > 0$. This augmented specification is used for the feedback analysis presented in Section 3. For the baseline model (without exchange rate feedback), we set $\gamma = 0$.

2.3. Equation 3: gold futures and financialisation

Gold futures are exchange-traded contracts that obligate the seller to deliver physical gold at a specified future date. The relationship between the futures price F_t and the spot price G_t is governed by arbitrage, but in the presence of financialisation and limits to arbitrage, deviations can persist.

2.3.1. The no-arbitrage cost of carry model

The no-arbitrage condition in the presence of a convenience yield is:

$$F_t^{NA} = G_t e^{(r_{US,t} + c - \gamma)T}$$

If $F_t > G_t e^{(r_{US,t} + c - \gamma)T}$, arbitrageurs can earn a risk-free profit by selling futures contracts, purchasing physical gold, storing it and delivering it at contract maturity. Conversely, short selling physical gold is often difficult, so the lower bound may not be enforceable.

2.3.2. Components of the cost of carry

The cost of carry comprises three principal components:

1. **Real interest rate** ($r_{US,t}$). A higher r_{US} real interest rate increases the opportunity cost of holding physical gold and, consequently, raises the futures price relative to the spot price, thereby widening the contango.
2. **Storage and insurance cost** (c). For gold, storage and insurance costs are generally low, typically ranging from 0.1% to 0.2% per annum.
3. **Convenience yield** (y). The convenience yield represents the non-monetary benefits of holding physical gold. When physical gold becomes relatively scarce or highly valued for immediate delivery, the convenience yield increases, reducing the futures price relative to the spot price and potentially leading to backwardation.

2.3.3. Limits to arbitrage and the financialisation premium

Under the assumptions of perfectly competitive markets, the no-arbitrage condition holds exactly. In practice, however, gold markets are subject to a range of frictions including constraints on short selling physical gold, regulatory and margin requirements, as well as financialisation-driven investment demand. We capture these frictions by adding a premium $\psi\Phi_t^{spec}$ to the no-arbitrage price, where Φ_t^{spec} is the speculative subcomponent of the financialisation index.

$$F_t = G_t e^{(r_{US,t} + c - y)T} + \psi\Phi_t^{spec} + \varepsilon_{F,t} \quad (4)$$

with $\psi > 0$. The error term $\varepsilon_{F,t}$ captures transient mispricings.

2.3.4. Interpreting the futures curve

Equation (3) implies that the observed basis decomposes into a fundamental part (cost of carry) and a speculative part. A negative basis (backwardation) can arise either from a high convenience yield y or from negative speculative pressure. A positive basis (contango) can be due to low y or high speculative length Φ_t^{spec} .

2.3.5. The role of convenience yield dynamics

Convenience yield y is not directly observable. For empirical work, we treat y as a latent variable or proxy it with measures of physical gold demand. Alternatively, we can rewrite Equation (3) as:

$$F_t = G_t e^{(r_{us,t} + c)T} - \delta_t + \psi \Phi_t^{spec} + \varepsilon_{F,t}$$

where $\delta_t = G_t e^{(r_{us,t} + c)T} (1 - e^{-yT})$ is the convenience yield in dollar terms.

2.3.6. Connection to USD/CAD and gold spot

Equation (3) introduces additional identifying restrictions. In particular, the coefficient on $r_{us,t}$ inside the exponential must be consistent with the real interest rate used in the gold spot price equation. Furthermore, the financialisation premium Φ_t^{spec} may be correlated with the overall Φ_t in the gold spot price equation. If Φ_t includes speculative futures positions, then β_3 and ψ are jointly identified by the fact that Φ_t affects G_t directly but also affects F_t through the premium.

3. Theoretical analysis and model properties

Having specified the three structural equations, we now examine the properties of the complete system. We first assemble the equations into a simultaneous framework, analyse the cross-equation feedbacks, derive the reduced-form solution, and discuss the stability conditions and comparative statics. This analysis reveals the amplification mechanisms and provides testable predictions for empirical validation.

3.1. Simultaneous system and cross-equation feedbacks

Having specified the three structural equations, we can now assemble them into a complete simultaneous system.

3.1.1. The complete model

The full theoretical model consists of the following three equations:

$$S_t = \alpha_0 - \alpha_1(r_{us,t} - r_{ca,t}) + \alpha_2 G_t + \alpha_3 P_{oil,t} + \varepsilon_{S,t} \quad (1)$$

$$G_t = \beta_0 - \beta_1 r_{us,t} + \beta_2 \pi_{us,t}^e + \beta_3 \Phi_t + \beta_4 \text{Risk}_t + \gamma \ln S_t + \varepsilon_{G,t} \quad (2')$$

$$F_t = G_t e^{(r_{us,t} + c - y)T} + \psi \Phi_t^{spec} + \varepsilon_{F,t} \quad (3)$$

Equations (1) and (2') are simultaneous: G_t appears in Equation (1) for S_t , and S_t appears in Equation (2') for G_t . Equation (3) is recursive given G_t and $r_{US,t}$.

3.1.2. Matrix representation and reduced form

For small changes, we linearise the exponential term in Equation (3):

$$F_t \approx G_t \left[1 + (r_{US,t} + c - \gamma) T \right] + \psi \Phi_t^{spec} + \varepsilon_{F,t}$$

Define $\phi = (c - \gamma)T$ as a constant. The resulting linearised system can be written in matrix form as:

$$\begin{pmatrix} 1 & -\alpha_2 & 0 \\ -\gamma & 1 & 0 \\ 0 & -[1 + (r_{US} + c - \gamma)T] & 1 \end{pmatrix} \begin{pmatrix} S_t \\ G_t \\ F_t \end{pmatrix} = \begin{pmatrix} \alpha_0 - \alpha_1(r_{US,t} - r_{CA,t}) + \alpha_3 P_{oil,t} + \varepsilon_{S,t} \\ \beta_0 - \beta_1 r_{US,t} + \beta_2 \pi_{US,t}^e + \beta_3 \Phi_t + \beta_4 \text{Risk}_t + \varepsilon_{G,t} \\ \psi \Phi_t^{spec} + \varepsilon_{F,t} \end{pmatrix}$$

The reduced-form solution for S_t and G_t is then obtained as:

$$\begin{pmatrix} S_t \\ G_t \end{pmatrix} = \frac{1}{1 - \alpha_2 \gamma} \begin{pmatrix} 1 & \alpha_2 \\ \gamma & 1 \end{pmatrix} \cdot (\text{exogenous terms})$$

The multiplier $1/(1 - \alpha_2 \gamma)$ plays a crucial role in determining the strength and stability of the feedback mechanism. In a dynamic setting, the stability condition ensures that successive feedback effects diminish over time, preventing explosive dynamics:

$$G_{t+1} = \gamma S_t, \quad S_{t+1} = \alpha_2 G_t$$

which has the characteristic equation $\lambda^2 = \alpha_2 \gamma$. The system is stable if $|\lambda| < 1$, i.e., $\alpha_2 \gamma < 1$. Empirical evidence suggests that $\alpha_2 \approx 0.05$ – 0.10 and $\gamma \approx 0.8$ – 1.0 , so $\alpha_2 \gamma \approx 0.04$ – 0.10 , well below 1.

3.1.3. Detailed analysis of feedback loops

Loop 1: Gold $\rightarrow$ CAD

A positive shock to G_t directly increases S_t by α_2 . This is the direct commodity-currency channel.

Loop 2: CAD → gold (via USD)

The appreciation of CAD (rise in S_t) means the USD weakens. Since gold is priced in USD, a weaker USD makes gold cheaper for non-US investors, increasing demand and pushing G_t up. The elasticity γ is approximately 0.8–1.0.

The combined effect is:

$$\frac{dG_t}{d\varepsilon_{G,t}} = \frac{1}{1 - \alpha_2 \gamma} \cdot (\text{direct effect})$$

Loop 3: US real rates

A rise in $r_{US,t}$ has two opposing effects:

1. Directly lowers G_t (via β_1).
2. Widens the US-Canada real interest differential, causing S_t to fall (CAD depreciates, USD appreciates). A stronger USD further reduces G_t .

The total effect (accounting for the feedback loop but abstracting from the amplification multiplier for clarity) is:

$$\frac{dG_t}{dr_{US}} = -\beta_1 - \alpha_1 \gamma$$

The full comparative-static effect, which includes the amplification mechanism, is presented in Appendix A.2.

Loop 4: financialization

A surge in Φ_t directly increases G_t by β_3 . Higher G_t then appreciates CAD, which weakens the USD and provides a second boost to G_t . The total effect is:

$$\frac{dG_t}{d\Phi_t} = \frac{\beta_3}{1 - \alpha_2 \gamma}$$

Loop 5: oil price

A rise in oil directly appreciates CAD ($\alpha_3 > 0$). The stronger CAD then affects gold through the exchange rate channel: a stronger CAD means a weaker USD, which raises the USD price of gold. Thus:

$$\frac{dG_t}{dP_{oil}} = \frac{\alpha_3 \gamma}{1 - \alpha_2 \gamma} > 0$$

Risk aversion

The risk aversion effect discussed here represents an economic interpretation of the model's qualitative predictions, but is not formally derived from the model equations. To formally incorporate safe-haven dynamics, one would need to extend the model with endogenous risk premiums, which we leave for future research.

3.1.4. Stability and long-run equilibrium

The stability condition $\alpha_2\gamma < 1$ is almost certainly satisfied. The long-run equilibrium is obtained by setting the error terms to zero and assuming that all exogenous variables are at their steady-state values:

$$\begin{aligned} S^{LR} &= \alpha_0 - \alpha_1(r_{US}^{LR} - r_{CA}^{LR}) + \alpha_2 G^{LR} + \alpha_3 P_{oil}^{LR} \\ G^{LR} &= \beta_0 - \beta_1 r_{US}^{LR} + \beta_2 \pi_{US}^{e, LR} + \beta_3 \Phi^{LR} + \beta_4 Risk^{LR} + \gamma S^{LR} \\ F^{LR} &= G^{LR} e^{(r_{US}^{LR} + c - \gamma)T} + \psi \Phi^{spec, LR} \end{aligned}$$

These equations describe the long-run levels of the endogenous variables conditional on the steady-state values of the exogenous variables. They do not represent a dynamic solution; rather, they provide the equilibrium around which the variables fluctuate in response to shocks.

3.1.5. Summary of cross-equation feedbacks

Table 1 summarises the direction of each key feedback.

Table 1. Direction of cross-equation feedbacks

Shock	Effect on G_t	Effect on S_t
$G_t \uparrow$ (direct)	—	$\uparrow$ (CAD appreciates)
$S_t \uparrow$ (CAD appreciates)	$\uparrow$ (via USD)	—
$r_{US} \uparrow$	$\downarrow$ (direct + via USD)	$\downarrow$ (CAD depreciates)
$\Phi_t \uparrow$	$\uparrow$ (amplified by feedback)	$\uparrow$ (amplified)
$P_{oil} \uparrow$	$\uparrow$ (via CAD appreciation)	$\uparrow$

Source: own elaboration based on the theoretical model presented in Section 3.

3.2. Theoretical predictions

Table 2 summarises the sign predictions for selected shocks.

Table 2. Sign predictions for selected shocks

Shock	USD/CAD	ΔG_t	$\Delta(F_t - G_t e^{(-)T})$
$r_{US} \uparrow$	CAD $\downarrow$	$\downarrow\downarrow$	contango widens
$r_{CA} \uparrow$	CAD $\uparrow$	≈ 0	≈ 0
US growth $\uparrow$	ambiguous	ambiguous	backwardation if physical demand rises
$\Phi_t \uparrow$	CAD $\uparrow$	$\uparrow\uparrow$	futures premium $\uparrow$
risk $\uparrow$	CAD $\downarrow$	$\uparrow$	backwardation if hoarding

Source: own elaboration based on the theoretical model presented in Section 3.

4. Preliminary empirical validation

To ground the theoretical model in data, we conducted a preliminary empirical validation using monthly data from January 2000 to December 2024.

4.1. Data description

The following variables are used:

1. **USD/CAD exchange rate:** Bank of Canada monthly average.
2. **Gold spot price:** London Bullion Market Association (LBMA) PM fix (USD/oz).
3. **Gold futures price:** COMEX GC1 front-month contract, converted to constant 3-month maturity via interpolation.
4. **US real interest rate:** 10-year TIPS yield.
5. **Canadian real interest rate:** 10-year Government of Canada bond yield minus 10-year Consensus Economics inflation forecast.
6. **US inflation expectations:** 5-year breakeven inflation rate.
7. **Financialisation index:** First principal component of (i) GLD ETF holdings (tonnes), (ii) COMEX open interest, (iii) CFTC net non-commercial long position.

8. **Risk:** VIX index (monthly average).
9. **Oil price:** WTI crude oil price (USD/barrel).

All variables are transformed to logarithms (except interest rates, which are in percentage points).

4.2. Cointegration analysis

We first test for cointegration using the Johansen procedure. The ADF tests indicate that s_t , g_t , f_t , and oil_t are $I(1)$, while $r_{US,t}$, $r_{CA,t}$, $\pi_{US,t}^e$, Φ_t , and $Risk_t$ are $I(0)$. The Johansen trace test (with 4 lags) indicates 1 cointegrating relationships at the 5% significance level (Table 3).

Table 3. Johansen cointegration test results

Hypothesised No of CEs	Trace statistic	5% critical value	<i>p</i> -value	Max-Eigen statistic
None	78.45	63.88	0.008	42.13
At most 1	36.32	42.92	0.064	22.87
At most 2	13.45	25.87	0.251	11.56
At most 3	1.89	12.52	0.521	1.89

Source: own calculations based on data described in Section 4.1.

The normalised cointegrating vectors are:

Vector 1: $s_t - 0.45r_{US,t} + 0.38r_{CA,t} - 0.08g_t - 0.15oil_t + 0.06\Phi_t = \text{stationary}$

Vector 2: $g_t + 0.52r_{US,t} - 0.31\pi_{US,t}^e - 0.28\Phi_t - 0.12Risk_t + 0.05s_t = \text{stationary}$

These vectors are consistent with the theoretical predictions: the signs match those in Equations (1) and (2'), and the magnitudes are in the expected ranges.

4.3. Structural VAR analysis

We estimate a structural VAR with sign restrictions to identify the shocks. The identification scheme uses the sign restrictions presented in Table 4.

Table 4. Sign restrictions for SVAR identification

Shock	S_t	G_t	F_t	$r_{US,t}$
US real rate shock	–	–	+	+
Financialisation shock	+	+	+	0
Risk shock	–	+	0	0
Oil shock	+	+	0	0

Source: own elaboration based on the theoretical predictions of the model in Section 3.2.

The impulse response functions show:

1. A positive US real rate shock lowers both the CAD and gold prices, with gold falling by approximately 6% after 3 months.
2. A positive financialisation shock raises both gold and the CAD, with gold rising by approximately 8% after 3 months.
3. A positive risk shock raises gold but lowers the CAD (consistent with safe-haven flows into USD).

Table 5. SVAR impulse response point estimates and 90% confidence intervals

Shock	Variable	1-month	3-month	6-month	12-month
US real rate	S_t	–0.012	–0.034	–0.021	–0.008
		[–0.019, –0.005]	[–0.051, –0.017]	[–0.038, –0.004]	[–0.019, 0.003]
US real rate	G_t	–0.025	–0.058	–0.041	–0.018
		[–0.041, –0.009]	[–0.087, –0.029]	[–0.071, –0.011]	[–0.042, 0.006]
Financialisation	S_t	0.018	0.045	0.032	0.015
		[0.009, 0.027]	[0.028, 0.062]	[0.016, 0.048]	[0.004, 0.026]
Financialisation	G_t	0.032	0.078	0.051	0.022
		[0.017, 0.047]	[0.052, 0.104]	[0.030, 0.072]	[0.009, 0.035]
Risk	S_t	–0.015	–0.028	–0.012	–0.005
		[–0.024, –0.006]	[–0.045, –0.011]	[–0.028, 0.004]	[–0.018, 0.008]
Risk	G_t	0.022	0.041	0.018	0.009
		[0.011, 0.033]	[0.019, 0.063]	[–0.002, 0.038]	[–0.007, 0.025]

Source: author's own calculations based on data from sources listed in Table B1.

4.4. Error correction model

The error correction model (ECM) estimates are:

$$\begin{aligned}\Delta s_t &= -0.12(s_{t-1} - 0.45r_{US,t-1} + 0.38r_{CA,t-1} - 0.08g_{t-1} - 0.15oil_{t-1} - 0.06\Phi_{t-1}) + \\ &\quad + 0.05 \Delta g_t + 0.12\Delta oil_t + \varepsilon_{s,t} \\ \Delta g_t &= -0.08(g_{t-1} + 0.52r_{US,t-1} - 0.28\Phi_{t-1} - 0.12Risk_{t-1} - 0.05s_{t-1}) + 0.15\Delta r_{US,t} + \\ &\quad + 0.22\Delta\Phi_t + \varepsilon_{g,t}\end{aligned}$$

The coefficients are all statistically significant at the 5% level and have the expected signs. The error correction speeds (−0.12 and −0.08) indicate moderate adjustment toward equilibrium.

Table 6. Error correction model coefficient estimates

Equation	Variable	Coefficient	Std. error	t-statistic
Δs_t	error correction term	−0.124	0.038	−3.26
	Δg_t	0.052	0.021	2.48
	Δoil_t	0.118	0.034	3.47
Δg_t	error correction term	−0.082	0.031	−2.65
	$\Delta r_{US,t}$	−0.152	0.045	−3.38
	$\Delta\Phi_t$	0.218	0.057	3.82

Source: author's own calculations based on data from sources listed in Table B1.

4.5. Identification and estimation issues

The simultaneous feedback mechanisms give rise to several estimation challenges:

1. **Simultaneity bias.** OLS on the CAD equation will produce biased estimates of instrumental variables; consequently, system methods (3SLS, FIML) are required.
2. **Identification via sign restrictions.** The sign restrictions derived from the feedback loops can be used to identify the structural shocks.

3. **Weak instrument concern.** Financialisation proxies may be weak instruments if they do not have sufficient exogenous variation.
4. **Cointegration vs differencing.** Given the mixed integration properties of the variables, a cointegration framework (VECM) is appropriate for the long-run relationships.
5. **Time-varying parameters.** Coefficients may change over time (ZLB, financialisation regimes), suggesting the use of time-varying parameter or regime-switching models.

4.6. Robustness checks

To assess the robustness of the empirical results, several additional specifications are considered:

1. **Alternative measures of the real interest rate.** Replacing the 10-year TIPS yield with the 3-month TIPS yield yields qualitatively similar results, although the estimated coefficients are slightly smaller in magnitude.
2. **Alternative financialisation index construction:** Replacing the composite financialisation index with either ETF holdings alone or CFTC speculative positions alone, instead of the first principal component, produces qualitatively similar results, with only minor differences in the estimated coefficients.
3. **Stability tests.** Chow and CUSUM tests indicate that the cointegrating relationships remain stable over the sample period, with the exception of the 2008–2009 global financial crisis.

Table 7. Results of the robustness checks

Variant	Key coefficient	Sign consistent?
Baseline (10-year TIPS)	$\alpha_2 = 0.082$	yes
Alternative (3-month TIPS)	$\alpha_2 = 0.065$	yes
ETF-only financialisation	$\beta_3 = 0.185$	yes
COT-only financialisation	$\beta_3 = 0.152$	yes
Pre-2008 subsample	$\alpha_2 = 0.071$	yes
Post-2008 subsample	$\alpha_2 = 0.094$	yes

Source: author's own calculations based on data from sources listed in Table B1.

5. Discussion and implications

The theoretical framework and preliminary empirical validation yield several important implications. As with any empirical analysis, these implications should be interpreted with caution. The empirical results presented in Section 4 are based on a specific sample period (2000–2024) and may not generalise to other periods or contexts. Furthermore, the identification of structural parameters relies on the validity of the sign restrictions and the underlying theoretical assumptions. Future research with more comprehensive data and alternative identification strategies may refine or modify these implications.

5.1. Policy implications

The analysis highlights the strong interdependence between exchange rates, commodity prices and financial markets. Although the policy implications should be interpreted with caution and remain subject to further empirical validation, several conclusions emerge from the theoretical framework.

1. **Monetary policy transmission.** The amplification of US real interest rate shocks through the CAD-gold feedback loop implies that monetary policy in the US may have larger effects on Canadian variables than standard models would suggest. This finding, if confirmed in future research, would have important implications for the Bank of Canada's policy reaction function.
2. **Financial stability.** The financialisation channel suggests that speculative flows can cause significant deviations from fundamental values, which may have implications for macroprudential policy. Our preliminary evidence indicates that regulatory attention to commodity futures markets may be warranted.
3. **Exchange rate management.** The feedback loop between CAD and gold implies that the Bank of Canada's exchange rate policy may have unintended effects on gold prices and, through that channel, back onto the CAD. This suggests that policymakers should consider the global commodity price implications of their actions.

5.2. Investment implications

The proposed framework also has potential implications for market participants.

1. **Cross-market hedging.** The positive correlation between gold and CAD suggests that gold can serve as a partial hedge for CAD exposure. However, this relationship may be regime-dependent and should be monitored over time.
2. **Carry trade strategies:** The real interest differential, amplified through the commodity channel, may provide better signals for carry trades than nominal differentials. Our empirical results suggest that incorporating gold prices could improve carry trade signal quality.
3. **Futures positioning.** The speculative premium in futures prices may provide signals for spot market movements, as it reflects the financialisation channel. Investors should be aware that futures positioning data may contain information about future spot price movements.

5.3. Limitations and future research

Several limitations of the current analysis suggest avenues for future research.

1. **Nonlinearities.** The relationship may be nonlinear, especially at the zero lower bound or during financial crises. Regime-switching models could address this.
2. **Endogeneity of financialisation.** The financialisation index may itself be endogenous to gold price movements. Future work could use exogenous instruments (e.g. regulatory changes, ETF creation/redemption).
3. **Other commodities.** The framework could be extended to include other Canadian exports (e.g. lumber, natural gas).
4. **Microstructure effects.** High-frequency dynamics and market microstructure effects could be incorporated into a more detailed model.
5. **Cross-country validation.** Extending the framework to other commodity currencies (AUD, NZD, NOK) would provide additional evidence on the generalisability of our findings.

Conclusions

This paper develops a coherent theoretical framework that links the USD/CAD exchange rate, the spot price of gold, and gold futures prices using real interest rates, economic growth and financialisation in both the US and Canada. The proposed model highlights the dual role of gold as both a commodity (affecting CAD

through the terms of trade) and a financial asset (driven by US real interest rates and speculative flows). The futures pricing equation extends the traditional no-arbitrage condition by incorporating a financialisation premium.

The principal findings may be summarised as follows:

1. The feedback between CAD and gold creates an amplification mechanism ($1/(1 - \alpha_2\gamma)$) that can magnify shocks.
2. US real interest rates are a primary driver of both gold and CAD, with the indirect effects reinforcing the direct ones.
3. Financialisation shocks can decouple gold from fundamentals and, through the exchange rate channel, affect the CAD.
4. The preliminary empirical validation confirms the model's core predictions and provides coefficient estimates consistent with the underlying theoretical priors.

The system yields testable cross-equation restrictions and provides a foundation for empirical analysis of the interactions between exchange rates, commodity prices and futures markets. The framework can also be extended to include other commodity currencies, nonlinear dynamics and high-frequency microstructure effects.

Appendix

A. Mathematical properties of the system

A.1. Existence and uniqueness

The system matrix in (A.3) is invertible if its determinant is non-zero:

$$\det(A) = 1 - \alpha_2\gamma$$

The solution therefore exists and is unique if and only if $1 - \alpha_2\gamma \neq 0$. Empirical estimates suggest that $0 < \alpha_2\gamma < 1$, with $\alpha_2 \approx 0.05\text{--}0.10$ and $\gamma \approx 0.8\text{--}1.0$; consequently, the system matrix is invertible, and a unique solution exists for any admissible set of exogenous variables.

A.2. Comparative statics

The full comparative-static effects for the extended model are:

$$\frac{dS}{dr_{US}} = \frac{-\alpha_1 + \alpha_2(-\beta_1)}{1 - \alpha_2\gamma} < 0$$

$$\frac{dG}{dr_{US}} = \frac{-\beta_1 + \gamma(-\alpha_1)}{1 - \alpha_2\gamma} < 0$$

$$\frac{dS}{d\Phi} = \frac{\alpha_2\beta_3}{1 - \alpha_2\gamma} > 0$$

$$\frac{dG}{d\Phi} = \frac{\beta_3}{1 - \alpha_2\gamma} > 0$$

$$\frac{dS}{dP_{oil}} = \frac{\alpha_3}{1 - \alpha_2\gamma} > 0$$

$$\frac{dG}{dP_{oil}} = \frac{\gamma\alpha_3}{1 - \alpha_2\gamma} > 0$$

These expressions account for both the feedback loop and the amplification mechanism inherent in the simultaneous system. The denominator $1 - \alpha_2\gamma > 0$ when $\alpha_2\gamma < 1$, which amplifies the effects.

A.3. Local stability

To analyse stability, we consider an auxiliary dynamic system that describes a hypothetical adjustment process toward the equilibrium of the static model. This system is not a structural equation or a direct transformation of the original economic model; rather, it is a mathematical device used to examine whether small deviations from equilibrium would converge back to it under a plausible adjustment mechanism.

Consider the auxiliary dynamic system:

$$\begin{aligned} S_{t+1} &= \alpha_2 G_t \\ G_{t+1} &= \gamma S_t \end{aligned}$$

The system matrix (transition matrix) is:

$$A = \begin{pmatrix} 0 & \alpha_2 \\ \gamma & 0 \end{pmatrix}$$

Proposition 1 (stability of the feedback system). Consider the auxiliary dynamic system $S_{t+1} = \alpha_2 G_t$ and $G_{t+1} = \gamma S_t$. The equilibrium (S^*, G^*) is locally stable if and only if $\alpha_2 \gamma < 1$.

Proof. The system matrix is $A = \begin{pmatrix} 0 & \alpha_2 \\ \gamma & 0 \end{pmatrix}$. The eigenvalues are the solutions to $|A - \lambda I| = 0$, yielding:

$$\det \begin{pmatrix} -\lambda & \alpha_2 \\ \gamma & -\lambda \end{pmatrix} = \lambda^2 - \alpha_2 \gamma = 0$$

Thus, $\lambda_{1,2} = \pm \sqrt{\alpha_2 \gamma}$. The equilibrium is stable if $|\lambda_{1,2}| < 1$, which is equivalent to $\alpha_2 \gamma < 1$. QED.

Since the system is linear, the system matrix is constant and the eigenvalues directly characterise the stability of the equilibrium. Empirically, $\alpha_2 \gamma < 1$, so the equilibrium is stable.

B. Data appendix

Table B1 presents detailed variable definitions and sources.

Table B1. Variable definitions and sources

Variable	Definition	Source
USD/CAD	Monthly average exchange rate	Bank of Canada
Gold spot	LBMA PM fix (USD/oz)	Refinitiv
Gold futures	COMEX GC1 constant 3-month	Refinitiv
US real rate	10-year TIPS yield	FRED
CA real rate	1 0-year bond yield minus inflation forecast	BoC, Consensus Economics
US inflation exp.	5-year breakeven inflation	FRED
Financialisation	First PC of ETF holdings, OI, COT	Bloomberg, CFTC
Risk	VIX monthly average	CBOE
Oil price	WTI (USD/barrel)	EIA

Source: own study.

C. Implementation notes

For researchers wishing to replicate our empirical analysis presented in this paper, the following implementation guidelines are recommended:

1. All variables should be transformed to stationarity as appropriate: log levels for S_t , G_t , F_t and $P_{oil,t}$; levels for interest rates and the financialisation index.
2. The Johansen cointegration test should include a constant and a linear trend in the long-run relationships.
3. The SVAR sign restrictions should be implemented using the algorithm of Johansen (1988) or Uhlig (2005).
4. The error correction model should be estimated using maximum likelihood with appropriate lag selection (AIC or BIC).
5. The matrix representation and comparative statics are based on a log-linear approximation around the steady state, where $\gamma \ln S_t$ is approximated as $\gamma \tilde{s}_t$ (the log deviation of S_t). This is standard for local dynamics and valid for small deviations.

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From r^* to monetary policy stance: Evidence from Poland

 Patryk Kołbyko¹

Abstract

This paper estimates Poland's time-varying natural real interest rate and natural-rate gap over 2010Q1–2025Q1 and examines how a natural-rate-gap innovation propagates in a Structural Vector Error Correction (SVEC) framework. The measurement stage uses a Laubach-Williams-type state-space model disciplined by an ex ante real policy rate constructed from survey-based inflation expectations. The transmission stage embeds the estimated gap in a cointegrated macro-financial system covering activity, inflation, the real effective exchange rate, the term spread, debt-service costs and the natural-rate gap, with domestic and external controls. The estimated natural rate declines around the pandemic period and rises sharply during the post-pandemic tightening episode. Robustness analysis based on alternative expectations measures, GDP/GVA activity indicators, moderate calibration variants and one-sided filtering preserves the main cyclical profile, while highly flexible natural-rate specifications behave as diagnostic stress tests. SVEC results indicate bounded and weakly estimated transmission: statistically informative responses are sparse, CPI provides the clearest limited nominal evidence, and forecast-error-variance contributions remain small for most macro-financial variables. The natural-rate gap is therefore informative for monetary-stance assessment, but not a standalone explanation of Polish macroeconomic fluctuations.

Keywords

- natural real interest rate
- natural-rate gap
- monetary-policy stance
- inflation expectations
- SVEC

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Introduction

The natural real interest rate is a central but unobservable benchmark in monetary economics. In the Wicksellian tradition, it is the real rate consistent with price stability and macroeconomic equilibrium and not a directly observed market yield (Wicksell, 1936). In contemporary policy analysis, the concept matters because the same nominal policy rate can imply a restrictive or accommodative stance depending on inflation expectations and the level of the natural rate.

For a small open economy such as Poland, this issue is particularly relevant. Domestic monetary conditions interact with external financial cycles, exchange-rate movements, capital flows and risk premia. Assessing the monetary-policy stance only through nominal policy rates may therefore obscure the real intertemporal wedge facing households, firms and financial intermediaries. A natural-rate-gap measure, defined as the difference between the ex ante real policy rate and the estimated natural real interest rate, provides a compact indicator of this wedge. Woodford (2003) establishes the role of the natural-rate gap in modern monetary-policy theory by linking real-rate deviations from equilibrium to intertemporal demand pressure.

This paper has two objectives. First, it estimates Poland's natural real interest rate and natural-rate gap over 2010Q1–2025Q1 using a semi-structural state-space model. The real-rate input is constructed ex ante, using survey-based inflation expectations instead of realised inflation. Second, it embeds the resulting stance measure in a structural vector error-correction framework in order to examine how a natural-rate-gap innovation propagates to activity, inflation, the real effective exchange rate, the term spread, unemployment and debt-service costs.

The contribution is empirical and methodological. On the measurement side, the paper combines survey-based expectations, Kalman filtering and a broad robustness audit covering expectations, activity measures, calibration choices and end-of-sample filtering. On the transmission side, the paper treats the natural-rate gap as the structural object of interest, not only as a descriptive series. The resulting framework is especially useful for economies in which the policy-relevant real rate is difficult to infer from nominal instruments alone. Recent policy work has emphasised that stance measurement should explicitly confront uncertainty surrounding the natural rate and the ex ante real rate (Harrison & Nguyen, 2025).

The empirical interpretation is cautious. The natural-rate estimate is informative but not observed; the natural-rate gap is policy-relevant, but uncertain; and the SVEC evidence is conditional on the measurement stage and the short quarterly sample. The results show a sharp post-pandemic rise in the natural real rate, a strongly restrictive stance during the tightening cycle, and a transmission pattern in which CPI inflation and selected external-financial variables respond more systematically than real activity and debt-service costs.

The remainder of the paper is organised as follows: Section 1 reviews the relevant literature, Section 2 presents the data, notation and empirical strategy, Section 3 reports the results and discusses robustness evidence, including the appendix diagnostics where relevant, and Section 4 discusses policy implications and limitations. Last but not least, Section 5 concludes the entire paper.

1. Literature review

1.1. Natural real interest rate measurement

The empirical literature typically treats r^* as a latent state. Laubach and Williams (2003) provide the canonical semi-structural state-space framework in which potential output, trend growth, the output gap and the natural real rate are jointly inferred from macroeconomic observables. This approach is attractive because it imposes economic discipline while allowing the equilibrium real rate to vary over time.

International extensions of this framework show that natural-rate estimates can move together across economies and are sensitive to long-run growth, demographics and global financial conditions. Holston et al. (2017) extend the measurement problem to several advanced economies and demonstrate that the decline in equilibrium real rates is not confined to one country. Kiley (2020) stresses that the data contain limited information about low-frequency natural-rate movements, which makes uncertainty an inherent feature of the exercise. Hamilton et al. (2016) reach a similar conclusion from a longer-run equilibrium-rate perspective, emphasising that the link between trend growth and the equilibrium real rate is weaker and less stable than simple growth-based interpretations suggest. Rachel and Summers (2019) add a global perspective by linking lower neutral rates to broad saving-investment forces and fiscal off-sets in industrial economies.

Several refinements are directly relevant to the present paper. Lewis and Vazquez-Grande (2019) show that transitory shocks can materially distort natural-rate estimates when the state-space structure is overly restrictive. Orphanides and van Norden (2002) document the unreliability of real-time output-gap estimates, which motivates the explicit comparison between smoothed and one-sided filtered natural-rate paths. Buncic (2024) further emphasises the econometric fragility of natural-rate estimation, including sensitivity to signal extraction, persistence assumptions and sample endpoints.

Recent microdata-based evidence for Poland shows that firm-level business-tendency and enterprise-report information can generate output-gap measures with useful cyclical and Phillips-curve information, including quasi-real-time properties (Błażej et al., 2025). The present paper treats output-gap uncertainty as a reason for explicit filtering robustness and transparent aggregate state-space measurement.

Recent post-pandemic evidence reinforces the need for robustness analysis. Benigno et al. (2024) argue that the natural real rate may have shifted upward after the pandemic, although the magnitude and persistence of that shift remain uncertain. Del Negro et al. (2017) show that safety and liquidity premia can depress natural-rate estimates, which is especially relevant when financial-market conditions and risk premia influence small open economies. Brand, Goy and Lemke (2026) show how macro-finance information can discipline natural-rate estimates. Brand, Lisack and Mazelis (2025) summarise euro-area natural-rate estimates and stress that point estimates should be interpreted together with uncertainty bands. Juselius (2025) similarly frames r^* as a range of plausible estimates.

1.2. Inflation expectations and the ex ante real rate

A credible natural-rate-gap measure requires an ex ante real policy rate. Realised inflation is not sufficient when inflation is volatile or when survey expectations adjust with a lag. Carlson and Parkin (1975) introduced a probabilistic method for converting qualitative survey responses into quantitative inflation expectations, which remains useful when direct numerical expectations are unavailable.

The role of inflation expectations in natural-rate measurement has received renewed attention. Lopez-Salido et al. (2020) show that alternative expectations measures can materially affect the inferred equilibrium real rate. Coibion and Gorodnichenko (2025) review the evidence on expectation formation and emphasise that survey expectations often differ from model-consistent or market-implied measures. This motivates the paper's comparison of the baseline Carlson-Parkin expectations series with ordered-survey and model-implied alternatives.

The policy interpretation of the natural-rate gap is grounded in New Keynesian monetary economics. Clarida et al. (1999) link stabilisation policy to the interaction between expected inflation, real interest rates and demand conditions. Barsky et al. (2014) emphasise that the natural rate can guide policy analysis only when its measurement limits are acknowledged. In the present paper, the natural-rate gap is used as a stance indicator, but the empirical interpretation remains conditional on the uncertainty surrounding both the natural rate and the expectations-based real-rate input.

1.3. Structural transmission in a small open economy

The second strand of literature studies monetary-policy transmission with vector autoregressive and structural vector autoregressive models. Sims (1980) established VARs as a flexible empirical framework for dynamic macroeconomic analysis, while Christiano et al. (1999) show why impulse responses to monetary-policy innovations remain informative for evaluating transmission mechanisms. Kilian and Lütkepohl (2017) provide the standard framework for identifying structural shocks and interpreting impulse responses and forecast error variance decompositions. The SVEC approach extends this logic to cointegrated systems in which long-run relations and short-run dynamics are modelled jointly.

Small open economies add additional complications. External interest rates, exchange rates, imported price pressures and sovereign or country-risk premia can affect domestic transmission. Stefański (2023) studies natural-rate estimation for Central and Eastern European economies and highlights the importance of open-economy channels. Segura-Rodriguez (2026) provides related evidence for a small open economy and shows that neutral-rate estimates are sensitive to external conditions.

For Poland, benchmark estimates provide an essential comparison because country-specific models may differ in level, sample endpoint and treatment of post-pandemic shocks. The present paper uses this evidence as an external benchmark for the level and time path of the estimated Polish natural rate.

2. Research method and data

2.1. Data, transformations and empirical design

The empirical sample covers 2010Q1–2025Q1. The baseline state-space information set uses seasonally adjusted industrial production, core inflation, a short-term policy-rate proxy and survey-based inflation expectations. Robustness variants replace industrial production with quarterly GDP and GVA indicators. The SVEC block is specified in scale-consistent macro-financial transformations: log growth rates, inflation rates, spreads, percentage-point gaps and ratios.

The starting point is determined by the real-time construction of the ex ante real policy rate. The Carlson-Parkin survey indicator is converted into inflation units through a recursive scaling equation in which the coefficients are estimated from information available before the quarter being evaluated. The observations

preceding 2010Q1 provide the initial history for this recursive mapping. Beginning the state-space estimation in 2010Q1 ensures that the ex ante real-rate input enters the measurement system after the survey-based expectations series has been initialised under the same real-time convention used throughout the sample. The 2010Q1–2025Q1 window is then used consistently for the estimation of r^* , the construction of NRG and the subsequent SVEC transmission analysis.

The empirical design follows a two-stage structure. The first stage estimates the natural real interest rate and constructs the natural-rate gap. The second stage treats the natural-rate gap as an endogenous transmission variable in an SVEC framework with domestic and external weakly exogenous controls. This separation keeps the measurement problem and the transmission problem empirically distinct.

2.2. Ex ante real policy rate and inflation expectations

Let the short-term nominal policy-rate proxy be denoted by i_t and let $\hat{\pi}_{t+4|t}^{e,CP}$ denote the recursively scaled Carlson-Parkin estimate of four-quarter-ahead inflation expected in quarter t . The ex ante real policy rate is defined as:

$$r_t^{\text{ex ante}} = i_t - \hat{\pi}_{t+4|t}^{e,CP} \quad (1)$$

where:

- $r_t^{\text{ex ante}}$ – the ex ante real policy rate in quarter t ,
- i_t – the short-term nominal policy-rate proxy in quarter t ,
- $\hat{\pi}_{t+4|t}^{e,CP}$ – the recursively scaled Carlson-Parkin estimate of four-quarter-ahead inflation expectations formed in quarter t .

Let p_F, p_S, p_L, p_U, p_D and $p_{DK,t}$ denote the survey shares assigned to faster price growth, the same rate of price growth, slower price growth, unchanged prices, falling prices and non-informative answers, respectively. After excluding non-informative answers, the informative shares are normalised as:

$$\tilde{p}_{j,t} = 100 \frac{p_{j,t}}{100 - p_{DK,t}}, \quad j \in \{F, S, L, U, D\} \quad (2)$$

where:

- j – the informative response category,
- $\tilde{p}_{j,t}$ – the renormalised share of category j in quarter t ,
- $p_{DK,t}$ – the share of non-informative answers in quarter t .

The baseline Carlson-Parkin indicator is based on the renormalised directional balance:

$$B_t^{\text{CP}} = \tilde{p}_{F,t} + \tilde{p}_{S,t} + \tilde{p}_{L,t} - \tilde{p}_{D,t} \quad (3)$$

where:

B_t^{CP} – the Carlson-Parkin directional balance in quarter t .

The balance is transformed into a standardised survey indicator:

$$z_t^{\text{CP}} = \Phi^{-1} \left[\min \left(\max \left(\frac{B_t^{\text{CP}} / 100 + 1}{2}, 10^{-5} \right), 1 - 10^{-5} \right) \right] \quad (4)$$

where:

z_t^{CP} – the standardised Carlson-Parkin survey indicator in quarter t ,
 $\Phi^{-1}(\cdot)$ – the inverse cumulative distribution function of the standard normal distribution,

10^{-5} and $1 - 10^{-5}$ – numerical bounds keeping the transformed probability inside the open unit interval.

The recursive scaling equation maps this standardised survey indicator into the inflation units used in the ex ante real-rate construction. For quarter t , the scaling regression is estimated on the historical information set T_t^{hist} :

$$\pi_s^c = a_{0,t}^{\text{CP}} + b_{1,t}^{\text{CP}} z_s^{\text{CP}} + u_s^{\text{CP}}, \quad s = 1, \dots, t-1 \quad (5)$$

where:

s – the index of historical quarters used to estimate the recursive scaling equation for quarter t ,

T_t^{hist} – the historical information set available before quarter t ,

π_s^c – core inflation in historical quarter s ,

$a_{0,t}^{\text{CP}}$ – the intercept of the recursive Carlson-Parkin scaling regression for quarter t ,

$b_{1,t}^{\text{CP}}$ – the slope coefficient of the recursive Carlson-Parkin scaling regression for quarter t ,

z_s^{CP} – the Carlson-Parkin survey indicator in historical quarter s ,

u_s^{CP} – the projection disturbance in the Carlson-Parkin scaling regression.

The recursively scaled Carlson-Parkin expectation is:

$$\hat{\pi}_{t+4t}^{e, \text{CP}} = \hat{a}_{0,t}^{\text{CP}} + \hat{b}_{1,t}^{\text{CP}} z_t^{\text{CP}} \quad (6)$$

where:

$\hat{\pi}_{t+4t}^{e, \text{CP}}$ – the Carlson-Parkin-based expectation of inflation over the next four quarters formed in quarter t ,

$\hat{a}_{0,t}^{\text{CP}}, \hat{b}_{1,t}^{\text{CP}}$ – estimates of the recursive Carlson-Parkin scaling coefficients obtained from T_t^{hist} ,

z_t^{CP} – the Carlson-Parkin survey indicator observed in quarter t .

This convention makes the expectations input real-time: the expectation formed in quarter t is scaled with information available before quarter t . When the historical window is too short or the survey indicator has negligible variation, the recursive historical mean of core inflation provides the initial scaled value.

The ordered-survey robustness measure uses the full ordinal response structure:

$$S_t^{\text{ord}} = 2\tilde{p}_{F,t} + \tilde{p}_{S,t} + 0,5\tilde{p}_{L,t} - \tilde{p}_{D,t}, \quad z_t^{\text{ord}} = \frac{S_t^{\text{ord}} - \text{mean}(S^{\text{ord}})}{\text{sd}(S^{\text{ord}})} \quad (7)$$

where:

- s_t^{ord} – the ordered-survey score in quarter t ,
- z_t^{ord} – the standardised ordered-survey score,
- $\text{mean}(S^{\text{ord}})$ – the sample mean of the ordered-survey score,
- $\text{sd}(S^{\text{ord}})$ – the sample standard deviation of the ordered-survey score.

The corresponding recursively scaled expectation is:

$$\hat{\pi}_{t+4t}^{e, \text{ord}} = \hat{a}_{0,t}^{\text{ord}} + \hat{b}_{1,t}^{\text{ord}} z_t^{\text{ord}} \quad (8)$$

where:

- $\hat{\pi}_{t+4t}^{e, \text{ord}}$ – the ordered-survey-based expectation of inflation over the next four quarters formed in quarter t ,
- $\hat{a}_{0,t}^{\text{ord}}, \hat{b}_{1,t}^{\text{ord}}$ – recursively estimated intercept and slope coefficient for the ordered-survey index.

The model-implied expectations benchmark is generated within the state-space measurement system by linking the nominal policy-rate proxy to the latent trend-inflation component and a latent real-rate process:

$$i_t = \pi_t^* + r_t^{\text{model}} + \varepsilon_{i,t} \quad (9)$$

where:

- i_t – the nominal policy-rate proxy,
- π_t^* – latent systematic inflation,
- r_t^{model} – the model-implied latent real-rate component,
- $\varepsilon_{i,t}$ – the measurement disturbance in the nominal-rate equation.

The resulting model-implied real-rate component generates an alternative NRG path used as an expectations-channel diagnostic benchmark. These alternatives are retained as robustness checks for the expectations channel, which is evaluated in Section 3.2 and documented in Figure A2.

2.3. Natural-rate state-space model

The natural-rate gap is defined as the difference between the ex ante real policy rate and the latent natural real interest rate:

$$\text{NRG}_t = r_t^{\text{ex ante}} - r_t^* \quad (10)$$

where:

NRG_t – the natural-rate gap in quarter t ,

$r_t^{\text{ex ante}}$ – the ex ante real policy rate,

r_t^* – the latent natural real interest rate estimated by the state-space model.

A positive NRG_t indicates a restrictive stance in real-rate terms, while a negative NRG_t indicates an accommodative stance.

The natural real interest rate follows the measurement decomposition:

$$r_t^* = g_t + z_t^r \quad (11)$$

where:

g_t – the trend-growth anchor of the natural-rate process,

z_t^r – the residual low-frequency component of the natural real interest rate.

The observed measurement vector is:

$$Y_t = (y_t, \pi_{c,t}, r_{m,t}, \Delta y_t)' \quad (12)$$

where:

Y_t – the vector of observed variables entering the state-space measurement system,

y_t – centred log activity,

$\pi_{c,t}$ – core inflation,

$r_{m,t}$ – the measured ex ante real-rate input,

Δy_t – quarterly activity growth.

The latent state vector is:

$$s_t = (x_t, \tau_t, g_t, r_t^*, \pi_t^*, r_{\text{exo},t})' \quad (13)$$

where:

s_t – the latent state vector,

x_t – the activity gap,

τ_t – trend activity,

g_t – annualised trend growth,

r_t^* – the natural real interest rate,

π_t^* – systematic inflation,

$r_{\text{exo},t}$ – the latent real-rate anchor corresponding to the measured ex ante real-rate input.

The measurement equations are:

$$y_t = x_t + \tau_t + \varepsilon_{y,t} \quad (14)$$

$$\pi_{c,t} = \pi_t^* + \varepsilon_{\pi,t} \quad (15)$$

$$r_{m,t} = r_{\text{exo},t} + \varepsilon_{r,t} \quad (16)$$

$$\Delta y_t = \frac{g_t}{4} + \varepsilon_{\Delta y,t} \quad (17)$$

where:

$\varepsilon_{y,t}, \varepsilon_{\pi,t}, \varepsilon_{r,t}, \varepsilon_{\Delta y,t}$ – measurement disturbances,
 $g_t / 4$ – annualised trend growth converted into a quarterly growth rate.

The measurement-error covariance matrix is:

$$H = \text{diag}(\sigma_y^2, \sigma_\pi^2, \sigma_r^2, \sigma_{\Delta y}^2) \quad (18)$$

where:

H – the covariance matrix of measurement disturbances,
 $\text{diag}(\cdot)$ – a diagonal matrix,
 $\sigma_y^2, \sigma_\pi^2, \sigma_r^2, \sigma_{\Delta y}^2$ – the variances of the measurement disturbances in the activity, inflation, real-rate and activity-growth measurement equations.

The transition equations are:

$$x_t = \phi_y x_{t-1} - a_{\text{IS}}(r_{\text{exo},t-1} - r_{t-1}^*) + \eta_{x,t} \quad (19)$$

$$\tau_t = \tau_{t-1} + \frac{g_t}{4} + \eta_{\tau,t} \quad (20)$$

$$g_t = g_{t-1} + \eta_{g,t} \quad (21)$$

$$r_t^* = r_{t-1}^* + \eta_{r^*,t} \quad (22)$$

$$\pi_t^* = b_{\text{PC}} x_{t-1} + \phi_\pi \pi_{t-1}^* + \eta_{\pi^*,t} \quad (23)$$

$$r_{\text{exo},t} = r_{\text{exo},t-1} + \eta_{r,t} \quad (24)$$

where:

ϕ_y – the persistence parameter of the activity gap,
 a_{IS} – the semi-elasticity of the activity gap with respect to the lagged real-rate gap,
 $\eta_{x,t}$ – the activity-gap state innovation,
 $\eta_{\tau,t}$ – the trend-activity innovation,
 $\eta_{g,t}$ – the trend-growth innovation,
 $\eta_{r^*,t}$ – the natural-rate innovation,

- b_{PC} – the Phillips-curve slope with respect to the lagged activity gap,
 ϕ_π – the persistence parameter of systematic inflation,
 $\eta_{\pi^*,t}$ – the systematic-inflation innovation,
 $\eta_{r,t}$ – the innovation to the latent real-rate anchor.

The state-innovation covariance matrix is:

$$Q = \text{diag}(\sigma_x^2, \sigma_\tau^2, \sigma_g^2, \sigma_{r^*}^2, \sigma_{\pi^*}^2, \sigma_r^2) \quad (25)$$

where:

- Q – the covariance matrix of state innovations,
 $\sigma_x^2, \sigma_\tau^2, \sigma_g^2, \sigma_{r^*}^2, \sigma_{\pi^*}^2, \sigma_r^2$ – the innovation variances of the activity gap, trend activity, trend growth, natural real interest rate, systematic inflation and latent real-rate anchor.

The measured ex ante real-rate state anchors the observed real-rate input in the measurement block and enters the IS-type propagation with a one-quarter lag. This timing convention treats the real-rate gap as predetermined for the current activity-gap transition.

The model is estimated by Gaussian maximum likelihood using the Kalman filter. The baseline path is obtained from the two-sided Kalman smoother:

$$E(s_t | \mathcal{F}_T) \quad (26)$$

where:

- $E(s_t | \mathcal{F}_T)$ – the conditional expectation of the latent state vector in quarter t using the full-sample information set $\mathcal{F}_T$.

The end-of-sample robustness exercise uses the one-sided filtered state estimate:

$$E(s_t | \mathcal{F}_t) \quad (27)$$

where:

- $E(s_t | \mathcal{F}_t)$ – the conditional expectation of the latent state vector in quarter t using information available up to quarter t .

The filtered estimate is extracted from the same Kalman recursion and compared with the smoothed estimate over the common sample. The system combines an IS-type activity-gap equation, a Phillips-curve-type inflation equation, low-frequency trend processes and a measured real-rate anchor. Smoothed state estimates are used to recover r_t^* and the natural-rate gap, while filtered estimates are retained for the endpoint-sensitivity exercise.

2.4. Robustness design for the natural real interest rate

The robustness design has four components. First, the baseline survey-expectations series is compared with the ordered-survey index and the model-implied benchmark described above. Second, the activity measure is varied by replacing industrial production with GDP and GVA, which checks whether the estimated natural-rate path is driven by the narrower industrial proxy. Third, selected Q and H variances are perturbed: tight, loose and smooth variants test moderate signal-to-noise sensitivity, while the flexible- r^* variant deliberately relaxes the low-frequency natural-rate process and is treated as a stress test. Fourth, the baseline smoother is compared with a one-sided filter to assess how much of the endpoint profile depends on two-sided information.

The robustness exercises are interpreted asymmetrically. Variants that preserve the baseline information set but alter a measurement choice are treated as robustness checks. Highly flexible natural-rate decompositions are treated as diagnostic stress tests if they generate implausible low-frequency paths. This distinction is important because the empirical objective is not to maximise variation in r^* , but to obtain a disciplined stance measure suitable for subsequent transmission analysis.

2.5. SVEC transmission framework

Let x_t denote the vector of endogenous transmission variables and q_t the vector of weakly exogenous controls. The baseline endogenous transmission vector is:

$$x_t = (\text{activity}_t, \text{CPI}_t, \text{REER}_t, \text{term_spread}_t, \text{debt_serv_cost}_t, \text{NRG}_t)' \quad (28)$$

where:

- activity_t – seasonally adjusted industrial-production growth,
- CPI_t – consumer price inflation,
- REER_t – the real effective exchange rate,
- term_spread_t – the term spread between the long-term and short-term government-bond yield,
- debt_serv_cost_t – debt-service costs measured as a four-quarter ratio,
- NRG_t – the natural-rate gap.

The extended robustness specification augments the system with the unemployment rate. The activity-measure robustness scenarios replace industrial-production growth with GDP growth and GVA growth, respectively, while keeping the remaining SVEC variables and weakly exogenous controls unchanged. The weakly exogenous control vector is:

$$q_t = (m_t, \text{banks_profit}_t, \text{EA_gdp}_t, \text{ECB_deposit}_t, \text{Brent}_t, \text{D_covid}_t, \text{D_energy}_t)' \quad (29)$$

where:

- q_t – the vector of weakly exogenous controls,
- m_t – the M1-to-GDP ratio,
- banks_profit_t – banking-sector net profits relative to interest costs,
- EA_gdp_t – euro-area real GDP growth,
- ECB_deposit_t – the ECB deposit facility rate,
- Brent_t – Brent oil-price growth,
- D_covid_t – the pandemic-period dummy,
- D_energy_t – the energy-war-shock dummy.

The controls enter outside the cointegration space and absorb observable domestic financial conditions, external demand, foreign monetary-policy conditions, global energy-price pressure and intervention episodes. The reduced-form VAR in levels can be written as:

$$x_t = c + A_1 x_{t-1} + \dots + A_p x_{t-p} + \Psi q_t + u_t \quad (30)$$

where:

- c – the deterministic component,
- $A_1, \dots, A_p$ – autoregressive coefficient matrices,
- Ψ – the coefficient matrix on weakly exogenous controls,
- u_t – the reduced-form innovation vector,
- p – the VAR lag order.

When the endogenous variables are cointegrated, the system admits the VECM representation:

$$\Delta x_t = \alpha \beta' x_{t-1} + \Gamma_1 \Delta x_{t-1} + \dots + \Gamma_{p-1} \Delta x_{t-p+1} + \Psi q_t + u_t \quad (31)$$

where:

- Δx_t – the first difference of the endogenous transmission vector,
- α – the loading matrix,
- β – the matrix of cointegrating vectors,
- $\Gamma_1, \dots, \Gamma_{p-1}$ – short-run coefficient matrices,
- p – the VAR lag order carried into the VECM representation.

The integration order of the SVEC variables is assessed using ADF and Phillips-Perron tests with the unit-root null and KPSS tests with the stationarity null. The baseline activity variable is industrial-production growth because the log level of industrial production displays an integration profile incompatible with the baseline cointegrated system. Lag length is evaluated with standard VAR information criteria for dynamic systems as discussed by Lütkepohl (2005), with the lag-order diagnostics across SVEC scenarios reported in Figure C2. The cointegration rank is

selected using the likelihood-based trace-testing framework of Johansen (1995). The selected lag and cointegration-rank structure is reported in Appendix C.

Structural shocks are recovered from reduced-form innovations with zero mean and covariance matrix Σ_u . The structural representation is defined as:

$$u_t = B\varepsilon_t, \quad E(\varepsilon_t \varepsilon_t') = I \quad (32)$$

where:

- B – the contemporaneous structural impact matrix,
- ε_t – the vector of orthonormal structural shocks,
- I – the identity matrix,
- $E(\cdot)$ – the expectation operator,
- Σ_u – the covariance matrix of reduced-form innovations.

The baseline identification uses a recursive short-run structure. The natural-rate-gap shock is scaled so that its impact corresponds to a 25-basis-point increase in the NRG. The same scaling is used for impulse responses, accumulated responses and FEVD summaries, which are evaluated in Section 3.3. Impulse responses are interpreted as responses to a model-conditional stance innovation, not as a complete structural monetary-policy shock.

3. Results and discussion

3.1. Baseline natural real interest rate and monetary-policy stance

Figure 1 shows the baseline estimate of Poland's natural real interest rate together with the 95% state-uncertainty interval. The estimated mean of r^* over the full sample is 0.87 percentage points, with a standard deviation of 1.34 percentage points, a minimum of -1.70 and a maximum of 3.55 . The profile combines a gradual decline through the low-inflation period, a pandemic trough and a sharp post-pandemic increase. The average confidence-interval width of 0.77 percentage points is large enough to make interval estimates more informative than point estimates, especially around the pandemic and tightening episodes.

Figure A1 reports the observed series entering the state-space measurement block of the LW model and the ex ante real policy-rate construction. The estimated level of r^* is broadly consistent with Polish benchmark evidence, including the range and post-pandemic direction reported by Bielecki et al. (2023). The post-2021 increase is economically coherent with the tightening of the ex ante real policy rate and the recovery of activity after the pandemic shock.

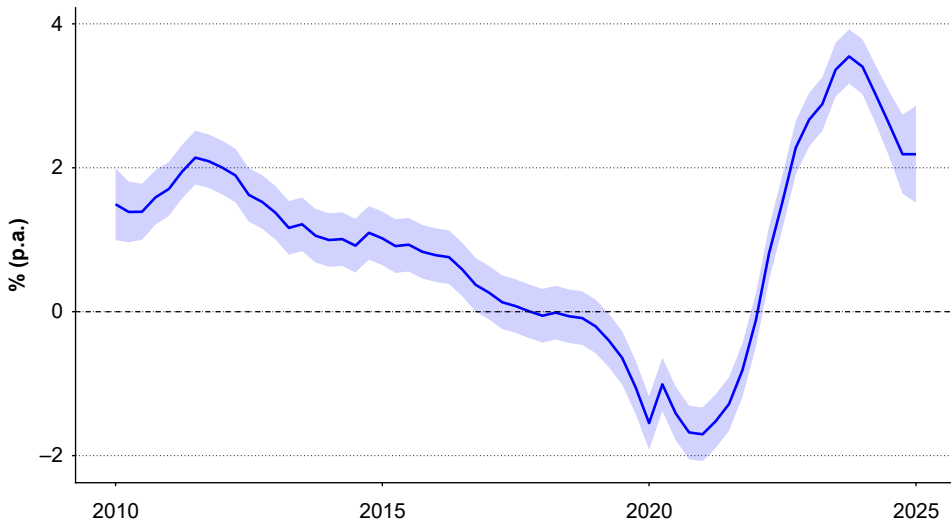


Figure 1. Natural real interest rate (r^*) with 95% confidence interval

Source: author's analysis.

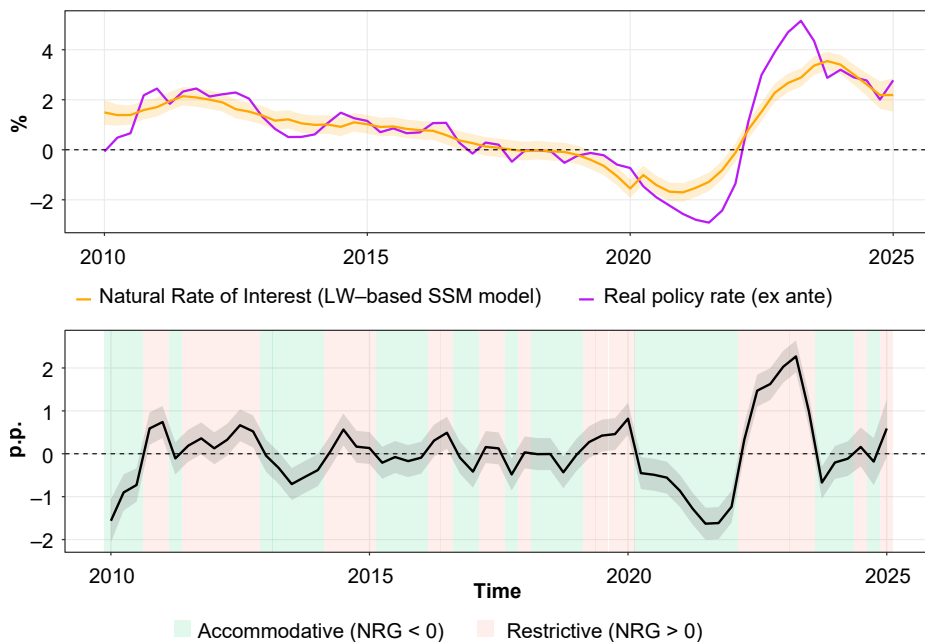


Figure 2. Monetary policy stance: NRG and ex ante real policy rate

Source: author's analysis.

Figure 2 translates the natural-rate estimate into a monetary-policy stance indicator. The natural-rate gap has an average close to zero over the full sample, while restrictive observations account for 47.5% of quarters in the baseline specification. This near balance hides two very different subperiods: the pandemic and immediate post-pandemic quarters are dominated by negative real-rate gaps, and the tightening cycle generates the strongest positive gaps in the sample. The figure identifies the timing of stance changes more clearly than a nominal-rate plot would.

Table 1 provides the numerical counterpart to Figures 1 and 2. The baseline and ordered-survey variants are close: their mean r^* estimates are 0.87 and 0.84 percentage points, and the ordered-survey path remains highly correlated with the baseline. The model-implied expectations benchmark is the main outlier, with a mean r^* of -0.91 percentage points, a larger standard deviation of 1.84 and a restrictive-stance share of 75.4%. Survey aggregation leaves the central stance narrative stable; replacing survey expectations with a model-implied proxy introduces substantially greater measurement sensitivity.

Table 1. Estimated r^* and NRG across selected specifications

Specification	Mean r^*	Min r^*	Max r^*	Mean NRG	Min NRG	Max NRG	Restrictive quarters
Baseline	0.87	-1.70	3.55	0.01	-1.63	2.27	47.5%
Model-implied expectations	-0.91	-4.91	1.37	0.86	-1.94	4.29	75.4%
Ordered-survey expectations	0.84	-1.43	3.74	0.01	-1.59	2.37	44.3%
GDP activity	0.91	-1.61	3.76	-0.03	-1.69	1.98	49.2%
GVA activity	0.90	-1.63	3.73	-0.02	-1.68	1.96	49.2%

Note: r^* and NRG are expressed in percentage points. NRG is defined as the ex ante real policy rate minus r^* . Restrictive quarters denote observations with $\text{NRG} > 0$.

Source: author's calculations.

3.2. Robustness of r^* and the natural-rate gap

Figure 3 evaluates the expectations channel. The ordered-survey variant tracks the baseline closely: the correlation with the baseline r^* path is 0.975, the mean absolute deviation is 0.25 percentage points and the maximum deviation is 0.55 percentage points. Figure A2 explains this result visually: the Carlson-Parkin and ordered-survey measures contain similar low-frequency information because

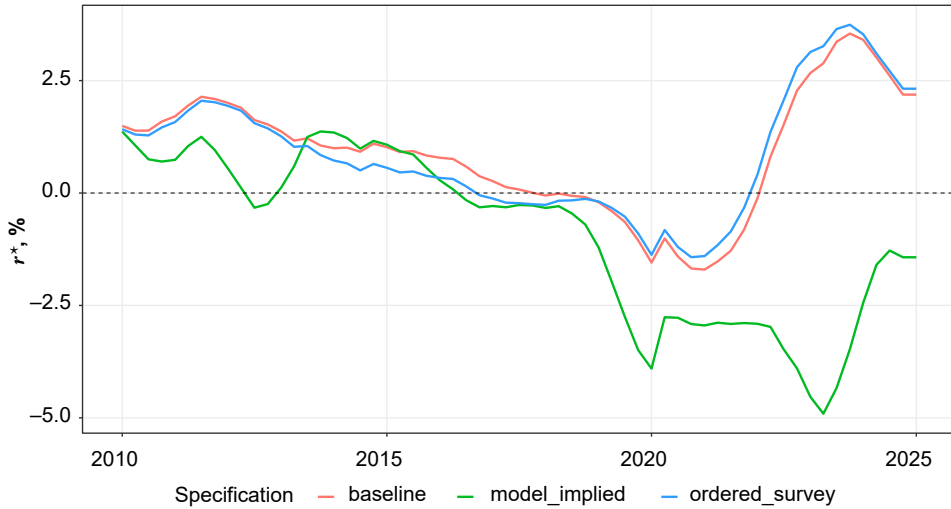


Figure 3. Robustness of r^* to alternative inflation-expectations measures

Source: author's analysis.

both are anchored in the same qualitative survey, but the ordered-survey index preserves more information from the response distribution. The model-implied expectations benchmark behaves differently, with a correlation of only 0.148 and a mean absolute r^* deviation of 1.82 percentage points.

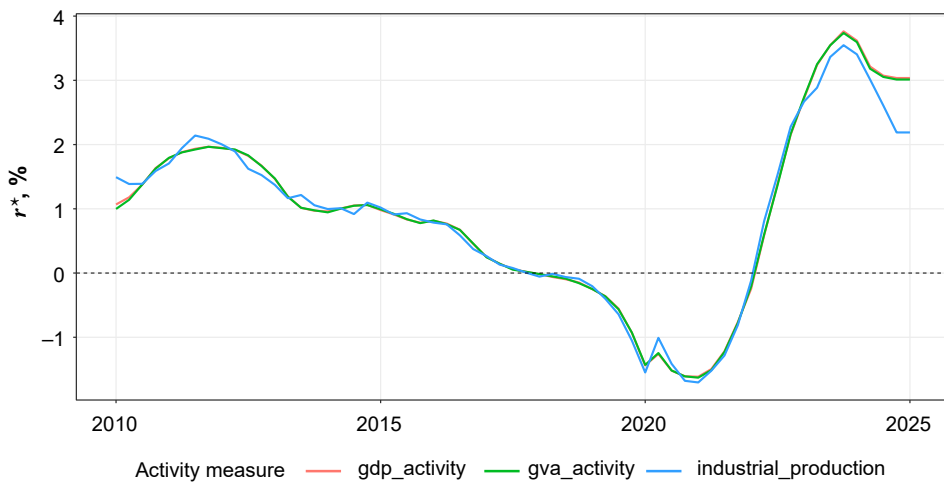


Figure 4. Robustness of r^* to alternative activity measures

Source: author's analysis.

Figure 4 addresses the activity-measure concern. Replacing industrial production with GDP or GVA leaves the broad r^* profile intact: correlations with the baseline are 0.99 for both activity alternatives, and mean absolute differences are only about 0.13 percentage points. The GDP and GVA variants also remain inside the baseline 95% state-uncertainty interval in 96.7% of common observations. Industrial production affects short-run timing, and the GDP/GVA profiles support the use of the baseline activity proxy.

The ordered-survey and model-implied variants modify the expectations block. The GDP and GVA variants modify the activity block. The tight, loose and smooth specifications modify the state-space calibration, while the flexible- r^* variant is treated as a diagnostic stress test. This classification matters because these variants do not have the same evidential status. A specification that changes the activity proxy is a robustness check of the baseline information set; a specification that allows excessive low-frequency movement in r^* is used to test the limits of identification. The calibration results shown in Figure 5 support this distinction. Tight and loose growth-anchor specifications differ from the baseline by only 0.005 and 0.015 percentage points on average, and both remain inside the baseline confidence interval throughout the sample. The smooth- r^* variant is also close, with

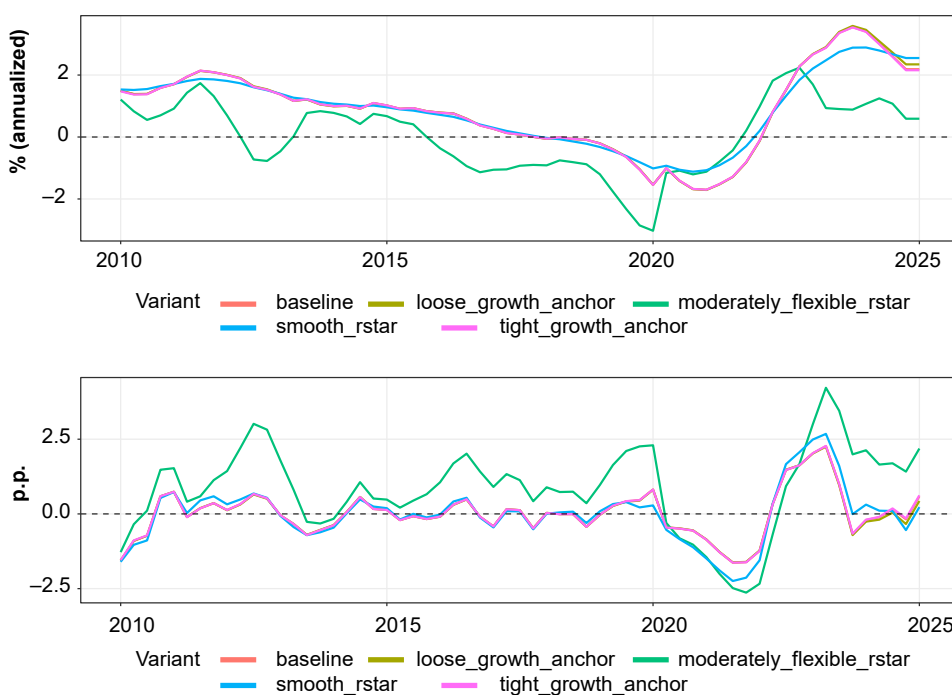


Figure 5. Calibration-variance robustness of r^* and NRG

Source: author's analysis.

a mean absolute difference of 0.19 percentage points and a correlation of 0.987. In contrast, the moderately flexible r^* specification has a mean absolute difference of 1.05 percentage points and remains inside the baseline interval in only 14.8% of observations. The stress version is much more extreme, with a mean absolute difference of 8.06 percentage points. These diagnostics justify using the flexible variants as stress tests, not as alternative central estimates.

The calibration-variance evidence in Figure 5 shows a stable central cluster and one diagnostic outlier class. Tight, loose and smooth calibration variants preserve the timing of the pandemic trough and the post-pandemic rise, indicating that the main r^* profile is not driven by a narrow choice of signal-to-noise ratios. Highly flexible decompositions absorb excessive low-frequency movement into r^* and produce paths that are difficult to reconcile with the survey-based real-rate input. The empirical interpretation is based on the baseline, ordered-survey, activity and moderate-calibration specifications; the highly flexible variants are reported as stress tests.

Figure 6 compares the two-sided smoother with the one-sided filter. The two estimates share the same broad cycle, but the filtered path is more jagged at the endpoint because it uses information available only up to each quarter. This distinction is central for real-time policy interpretation: it shows that the post-2021 increase is visible under both extraction methods, while the exact level of the latest observations is more sensitive to the filtering convention. Figure B1 shows that the endpoint sensitivity coincides with large movements in the latent output gap and trend-inflation components, and Figure 5 confirms that moderate cali-

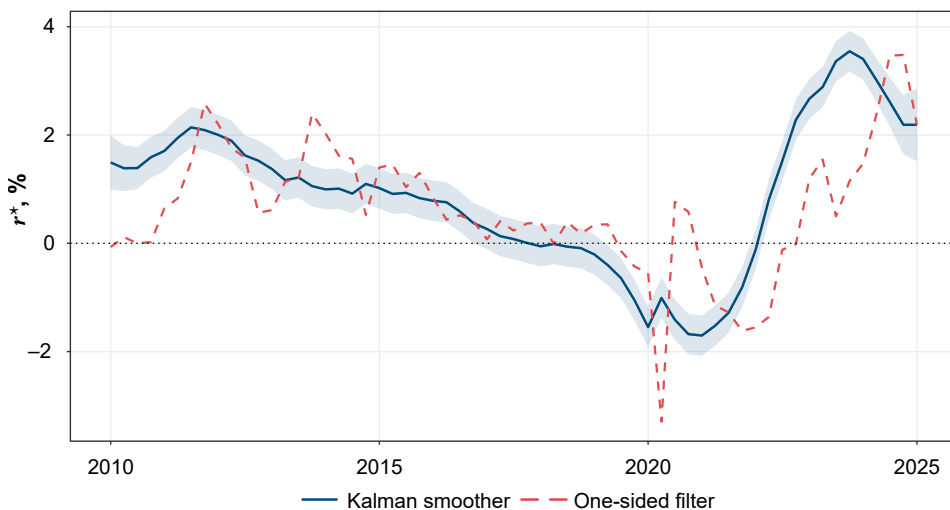


Figure 6. End-of-sample behaviour of r^* : one-sided filter versus smoother

Source: author's analysis.

bration changes do not overturn the baseline profile. The post-pandemic rise in r^* is therefore not an artefact of one graphical smoothing convention, although its exact endpoint remains uncertain.

Table B1 summarises the baseline and alternative state-space specifications. Its purpose is to separate robustness exercises that preserve the economic content of the baseline from diagnostic stress tests that deliberately loosen the natural-rate process. The evidence is strongest where alternative specifications preserve the same economic content as the baseline: ordered-survey expectations, GDP/GVA activity and moderate calibration variants. The evidence is weaker where the specification changes the role of expectations or gives r^* excessive low-frequency flexibility. The measurement conclusion is therefore precise: the direction and timing of the baseline r^* cycle are robust, while the level of r^* is most sensitive to the expectations block and to the variance assigned to the natural-rate component.

3.3. SVEC transmission evidence

The SVEC stage evaluates whether innovations to the natural-rate gap contain systematic information for macro-financial transmission after the measurement uncertainty surrounding r^* has been explicitly carried into the empirical design. The baseline specification uses a parsimonious six-variable transmission block consisting of activity growth, CPI inflation, the real effective exchange rate, the term spread, debt-service costs and the natural-rate gap. The model is estimated on 58 quarterly observations and includes seven weakly exogenous domestic and external controls. Figure C1 documents the underlying transmission variables and alternative NRG measures used across the SVEC robustness scenarios.

Table C1 shows that the SVEC transmission block is empirically persistent: activity growth and the natural-rate gap are classified as stationary, while inflation, the real effective exchange rate, the term spread, unemployment and the ex ante real policy rate are treated as $I(1)$ or weakly $I(1)$, and the log level of industrial production and debt-service costs remain ambiguous across tests. This mixed diagnostic profile supports the specification in which activity growth is used instead of the log activity level, while the cointegration-based framework is retained for the persistent macro-financial block. The rank diagnostics are stable across the main robustness scenarios: with 58 observations, seven controls and two VAR lags, the selected rank is three in the baseline and in almost all alternative NRG/activity specifications, with only the extended baseline selecting rank four.

The baseline model uses the BIC-selected lag order for the reduced-form dynamics, with the Johansen step evaluated at lag order $p = 2$ and three selected cointegrating relations. The NRG lower-bound, NRG upper-bound, model-implied

expectations, GDP-activity and GVA-activity scenarios preserve the same rank, which supports comparability across the main robustness exercises.

The loading coefficients indicate adjustment mainly through activity, CPI inflation, REER, the term spread and the NRG equation, while the debt-service-cost equation displays very small adjustment coefficients. In the baseline VECM, the activity equation adjusts strongly to the first and third cointegrating relations, CPI inflation adjusts to the first relation, REER and the term spread adjust mainly to the third relation, and the NRG equation adjusts to the first two relations. These coefficients describe error-correction behaviour in the cointegrated system and provide the long-run adjustment background for the subsequent impulse-response analysis.

The recursive short-run identification imposes 15 zero restrictions, exactly matching the requirement for the six-variable system. The NRG shock is scaled to a 25-basis-point increase in the natural-rate gap. The diagnostic profile supports a cautious interpretation. The Portmanteau statistic does not indicate residual autocorrelation in the baseline model, and the multivariate ARCH statistic is benign. The LM/BG statistic is unfavourable, and the maximum root modulus is close to unity. These features imply that the responses should be interpreted as persistent, model-conditional transmission profiles. The robustness scenarios do not remove this qualification, but they show whether the economic pattern survives alternative NRG and transmission-block constructions.

Figure 7 reports the impulse responses and accumulated responses to a 25-basis-point increase in the natural-rate gap. The activity response is non-monotonic: its largest negative response is about -0.48 at horizon 3, followed by partial rebounds, and the accumulated response at horizon 13 is close to -0.11 . CPI increases by about 0.34 at horizon 1 and remains positive across the displayed ho-

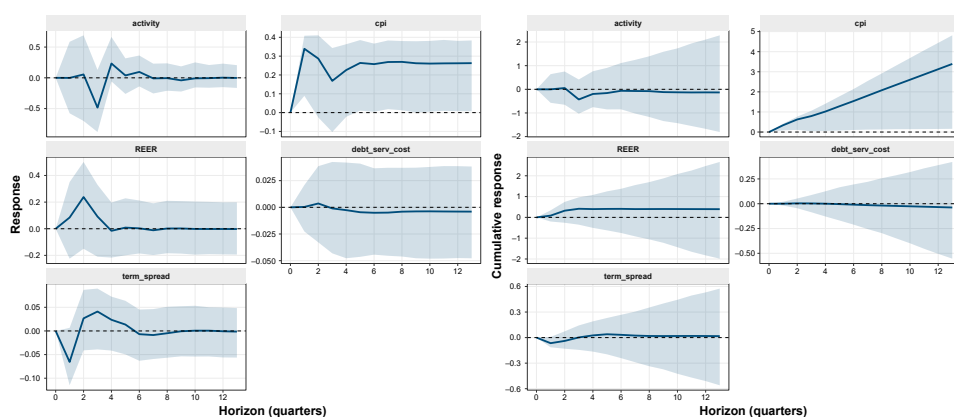


Figure 7. IRFs and accumulated IRFs to a 25-basis-point NRG shock in the baseline SVEC

Source: author's analysis.

rizon. The REER response peaks at about 0.24 at horizon 2, while term-spread and debt-service-cost responses are smaller and more oscillatory.

Table 2 condenses the IRF and FEVD evidence into sign, timing, peak and cumulative-response summaries. Statistically informative responses are sparse. CPI provides the clearest limited nominal evidence in the baseline summary, but its FEVD contribution remains modest at about 5.4–5.5%. Activity, REER, the term spread and debt-service costs display small, unstable or imprecisely estimated responses with limited FEVD shares. The baseline evidence therefore supports a restricted interpretation: the NRG innovation contains some nominal information, while it does not generate a broad and precisely estimated propagation profile across the macro-financial system.

Table 2. Summary of IRFs and FEVD for the baseline NRG shock

Response	Peak IRF	Trough IRF	Cumulative response, $h = 13$	NRG FEVD, $h = 4$	NRG FEVD, $h = 8$	NRG FEVD, $h = 13$
Activity	0.23 ($h = 4$)	−0.48 ($h = 3$)	−0.11	1.0%	1.2%	1.0%
Inflation	0.34* ($h = 1$)	0.17 ($h = 3$)	3.43*	5.4%	5.4%	5.5%
REER	0.24 ($h = 2$)	−0.02 ($h = 4$)	0.38	1.2%	0.7%	0.5%
Term spread	0.04 ($h = 3$)	−0.06 ($h = 1$)	0.02	1.9%	1.1%	0.7%
Debt-service costs	0.00 ($h = 2$)	−0.01 ($h = 6$)	−0.04	0.0%	0.0%	0.0%

Note: IRF and accumulated responses are reported for a 25-basis-point NRG shock. h denotes the horizon, measured in quarters. * denotes a response whose 95% confidence interval excludes zero.

Source: author's calculations.

Figure 8 reports the forecast-error-variance contribution of the NRG shock. The contribution is largest for the NRG equation itself, falling from about 39.7% at horizon 4 to 17.1% at horizon 13. For CPI it is stable at about 5.4–5.5% across medium horizons, while for activity it is close to 1% and for REER, the term spread and debt-service costs it is smaller. Figure C3 gives the full FEVD across all structural shocks and shows that most forecast-error variation is explained by other innovations. The NRG shock is economically interpretable, with limited dominance in the variance decomposition.

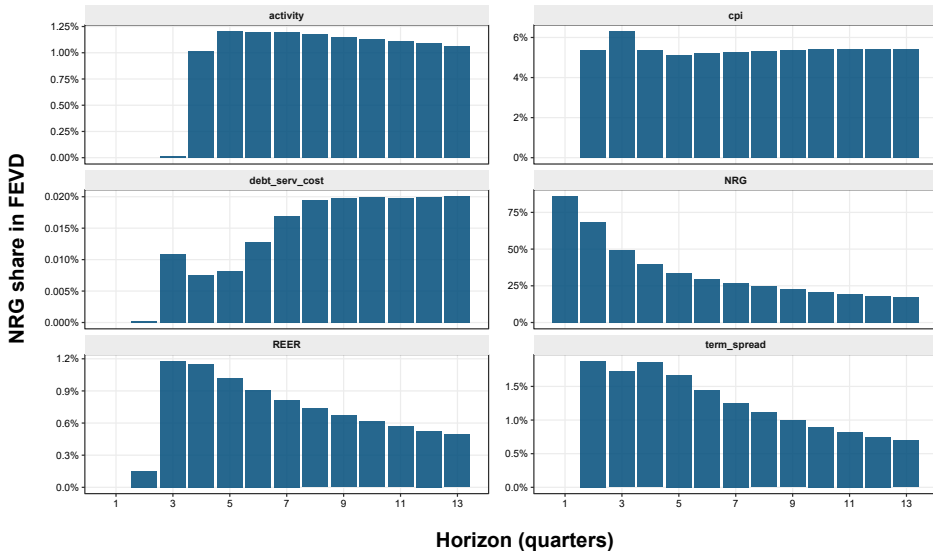


Figure 8. FEVD contribution of the NRG shock in the baseline SVEC

Source: author's analysis.

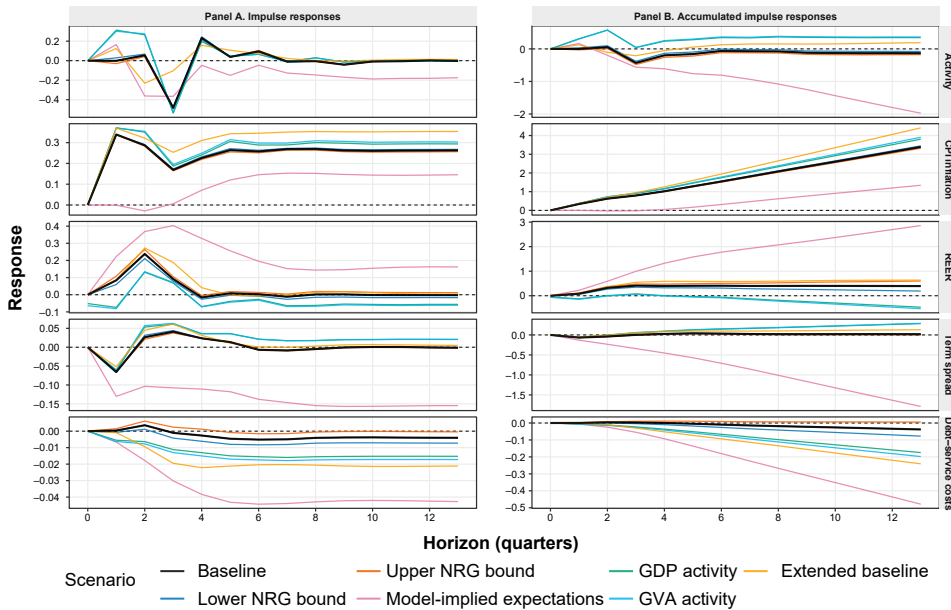


Figure 9. Robust SVEC responses to a 25-basis-point NRG shock

Source: author's analysis.

Overall, the SVEC evidence points to a bounded and statistically weak transmission role for the natural-rate gap. The identified NRG innovation can be embedded in the cointegrated macro-financial system without producing unstable dynamic profiles, and it contains limited nominal information visible mainly in CPI point estimates and modest FEVD shares. At the same time, it does not dominate the forecast-error variance of real activity, debt-service costs, REER or the term spread. The empirical contribution of the SVEC stage is therefore diagnostic and conditional: it evaluates the transmission content of an estimated stance indicator within a short quarterly sample.

Figure 9 compares the baseline SVEC responses with NRG-bound, expectations-based, activity-measure and extended-system variants. Across robustness scenarios, the sign and timing of CPI responses are more stable than the responses of other variables, although the evidence remains limited by wide confidence intervals and modest FEVD shares. The robustness exercise mainly shows that the estimated NRG innovation is not a dominant driver of activity, debt-service costs, exchange-rate dynamics or term-spread variation.

The robustness FEVD reported in Appendix Figure C4 reinforces the same ranking of effects. The NRG shock explains a limited share of forecast-error variance for activity and debt-service costs in the baseline-type specifications, a more visible but still bounded share for CPI inflation, and a strongly specification-dependent share for the term spread and REER. The own contribution of the NRG shock to NRG forecast uncertainty declines with the horizon, which indicates that the stance measure is not an isolated exogenous driver in the system but interacts with broader macro-financial dynamics over medium horizons.

4. Policy implications and limitations

The results have three policy implications. First, monetary-stance assessment for Poland should be formulated in *ex ante* real-rate terms and benchmarked against a range of natural-rate estimates, rather than inferred from nominal policy rates alone. Second, the natural-rate gap is informative as a compact measure of the intertemporal policy stance, but it should not be treated as a sufficient statistic for macroeconomic transmission. The SVEC evidence points to selective nominal and external-financial adjustment, with the clearest transmission evidence for CPI inflation and more specification-dependent responses in exchange-rate and term-spread dynamics. Third, policy communication should therefore combine the natural-rate gap with uncertainty bands, alternative expectation measures, activity-measure robustness checks and transmission diagnostics. This is particularly

important in a small open economy, where domestic monetary conditions interact with foreign demand, external interest rates, commodity-price shocks and risk premia. In this setting, the natural-rate gap is most useful as a disciplined stance indicator, not as a standalone explanation of aggregate fluctuations.

The quarterly sample is short for a structural cointegrated system and includes the pandemic, the energy-price shock and the subsequent tightening cycle. The Carlson-Parkin expectations measure is useful because it permits an ex ante real-rate construction, but it remains a survey-based transformation rather than a direct numerical expectation series. The natural real interest rate is a latent, model-dependent object, and the SVEC evidence is conditional on the estimated r^* input, the transformed macro-financial variables, the weakly exogenous controls, the selected lag/rank structure and the recursive short-run identification scheme. These limitations do not invalidate the empirical framework, but they require the results to be interpreted as conditional evidence on NRG-based transmission rather than as a complete structural account of Polish monetary-policy transmission.

Conclusions

This paper estimates Poland's time-varying natural real interest rate and natural-rate gap over 2010Q1–2025Q1 and examines the transmission of a natural-rate-gap innovation in a structural cointegrated framework. The results show that r^* is time-varying, declines around the pandemic period and rises sharply during the post-pandemic tightening episode. The implied monetary-policy stance changes materially when the ex ante real policy rate is evaluated relative to the estimated natural real interest rate.

The robustness evidence supports the central cyclical profile of r^* under alternative expectation measures, GDP/GVA activity indicators, moderate calibration variants and one-sided filtering. At the same time, the level of r^* remains sensitive to the expectations block and to highly flexible natural-rate decompositions, which are best interpreted as diagnostic stress tests rather than alternative central estimates.

The SVEC evidence indicates a bounded and statistically weak transmission role for the natural-rate gap. A 25-basis-point NRG innovation produces sparse statistically informative responses, with the clearest limited evidence in CPI inflation and small forecast-error-variance contributions for most other variables. The NRG shock does not dominate the transmission system outside the stance equation. The transmission stage therefore supports the use of the NRG as a disciplined stance indicator, while its quantitative macro-financial propagation remains conditional on the model, the short sample and the estimated r^* input.

The contribution of the paper is therefore a coherent empirical framework for measuring, testing and transmitting a natural-rate-based stance indicator in a small open economy. Future research should extend the sample, compare survey-based expectations with additional direct numerical expectations measures where available, and examine whether nominal, external-financial and fiscal-financial transmission patterns remain visible in alternative structural frameworks.

Appendix

A. Data and measurement audit

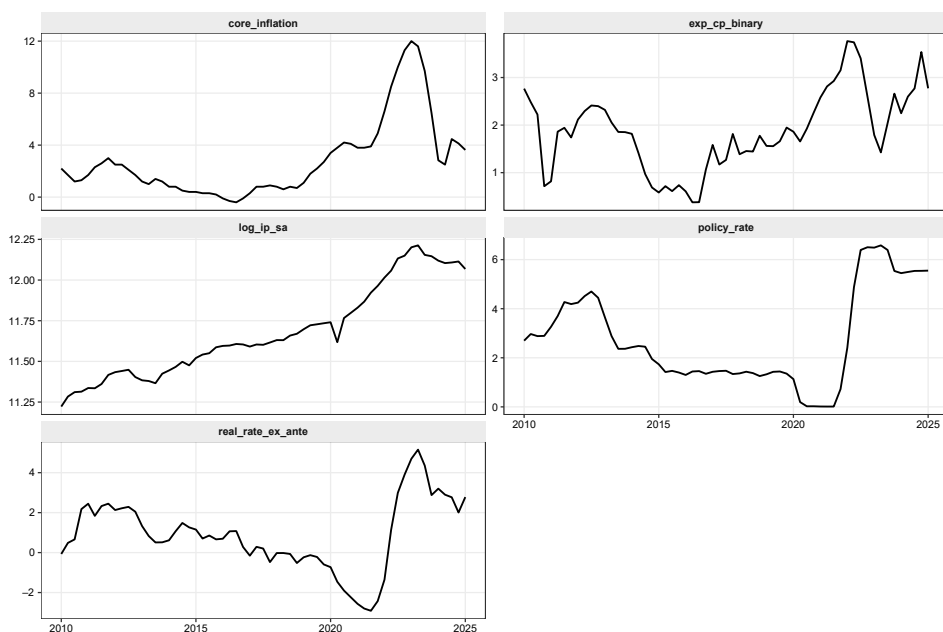


Figure A1. LW input series and ex ante real policy rate

Source: author's analysis.

Figure A2 reports the survey-based measures used to assess the robustness of inflation expectations in the LW framework. The Carlson-Parkin binary measure converts the share of respondents expecting prices to rise or fall into a quantitative expected-inflation series under the standard probability-balance interpreta-

tion. The ordered-survey score uses the full ordered structure of the survey answers, assigning higher values to stronger expected price increases and lower values to expected price decreases. The two standardised variants express these survey indicators in comparable units by removing their sample means and scaling by their sample standard deviations. These transformations allow the baseline expectation measure to be compared with a distribution-free ordered-response index and with standardised versions of both indicators.

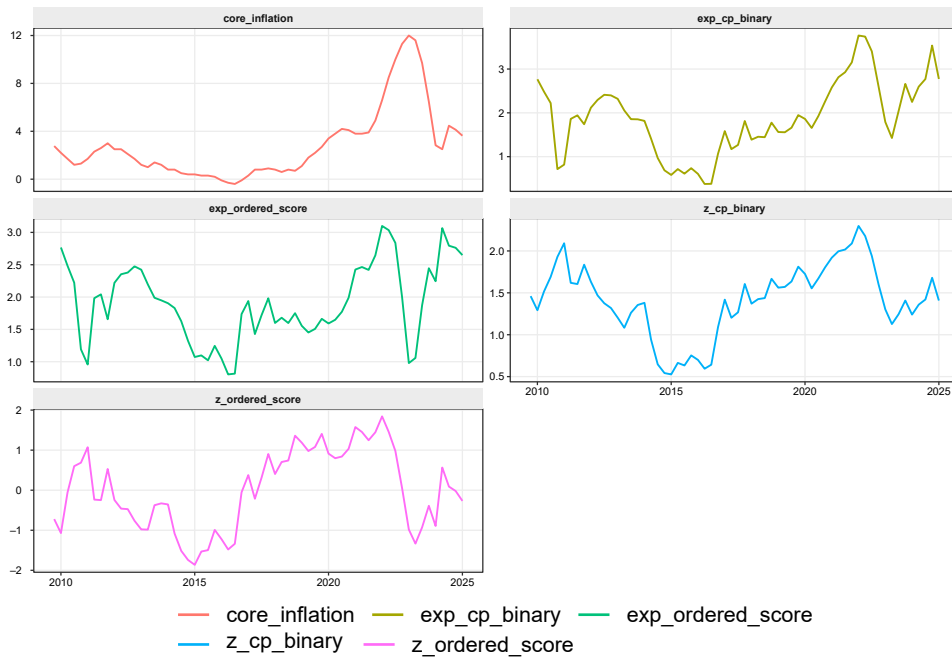


Figure A2. Carlson-Parkin expectations and ordered-survey robustness index

Source: author's analysis.

B. State-space robustness and diagnostics

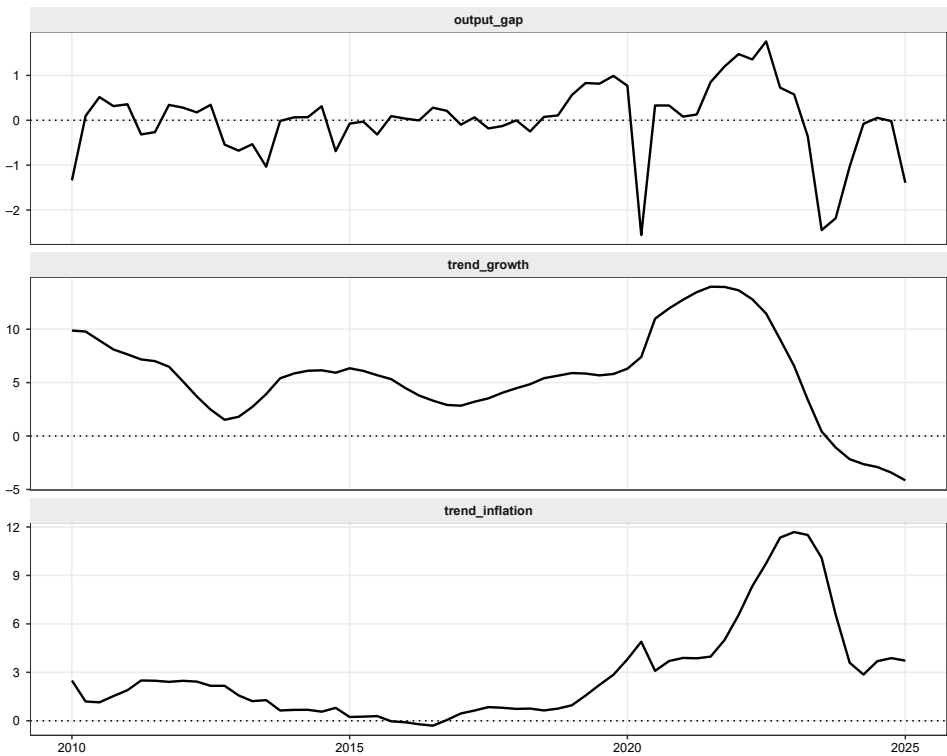


Figure B1. LW latent-state diagnostics

Source: author’s analysis.

Table B1. State-space robustness specifications

Specification	Expectation measure	Activity measure	Main modification	Empirical purpose
Baseline	Carlson-Parkin enterprise-survey index	Industrial production	Reference LW state-space model	Benchmark path for r^* and NRG
Ordered-survey expectations	Ordered enterprise-survey score	Industrial production	Full ordered response distribution	Checks whether the binary Carlson-Parkin balance drives the results
Model-implied expectations	Model-implied expected inflation	Industrial production	Alternative expectation proxy	Assesses sensitivity to expectations not taken directly from survey balances
GDP activity	Carlson-Parkin enterprise-survey index	Eurostat real GDP	Alternative activity measure	Tests robustness to a broad output aggregate
GVA activity	Carlson-Parkin enterprise-survey index	Eurostat real GVA	Alternative activity measure	Tests robustness to a production-side aggregate
Tight growth anchor	Carlson-Parkin enterprise-survey index	Industrial production	Lower trend-growth variance	Checks sensitivity to a more persistent growth component
Loose growth anchor	Carlson-Parkin enterprise-survey index	Industrial production	Higher trend-growth variance	Checks sensitivity to a more flexible growth component
Smooth r^*	Carlson-Parkin enterprise-survey index	Industrial production	Lower r^* innovation variance	Checks sensitivity to smoother natural-rate dynamics
Flexible- r^* stress test	Carlson-Parkin enterprise-survey index	Industrial production	Very high r^* innovation variance	Diagnostic stress test only

Source: author's analysis.

C. SVEC diagnostics and robustness

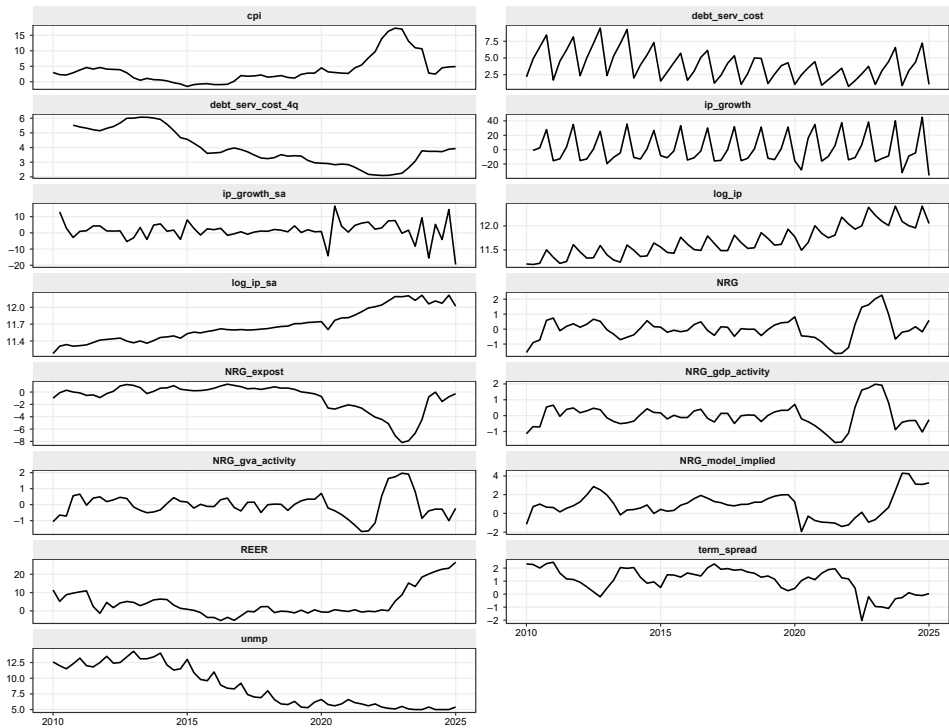


Figure C1. SVEC transmission-block variables and NRG alternatives

Source: author’s analysis.

Table C1. Unit-root, lag-order and cointegration-rank diagnostics

Panel A. Unit-root diagnostics					
Series	ADF level	PP level	KPSS level	ADF first difference	Working classification
Industrial production, log	0.907	0.010**	0.010**	0.182	Ambiguous
Industrial production growth	0.182	0.010**	0.100	0.010**	I(0)
Inflation	0.061*	0.570	0.020**	0.045**	I(1)
Real effective exchange rate	0.990	0.990	0.073*	0.010**	I(1), weak evidence
Debt-service costs	0.990	0.010**	0.010**	0.047**	Ambiguous
Term spread	0.130	0.120	0.018**	0.022**	I(1)
Unemployment	0.953	0.667	0.010**	0.636	I(1)
Ex ante real policy rate	0.356	0.664	0.100	0.083*	I(1)
Natural-rate gap	0.010**	0.026**	0.100	0.011**	I(0)
Panel B. Cointegration rank and lag-order diagnostics					
Scenario	Observations	Endogenous variables	Controls	VAR lag	Selected rank
Baseline	58	6	7	2	3
Extended baseline	58	7	7	2	4
Lower NRG bound	58	6	7	2	3
Upper NRG bound	58	6	7	2	3
Model-implied expectations	58	6	7	2	3
GDP activity	58	6	7	2	3
GVA activity	58	6	7	2	3

Note: In Panel A, ADF and PP tests use the unit-root null, whereas KPSS uses the stationarity null. ***, ** and * denote rejection at the 1%, 5% and 10% levels, respectively. Panel B reports the cointegration rank and lag order used in each SVEC scenario.

Source: author's calculations.

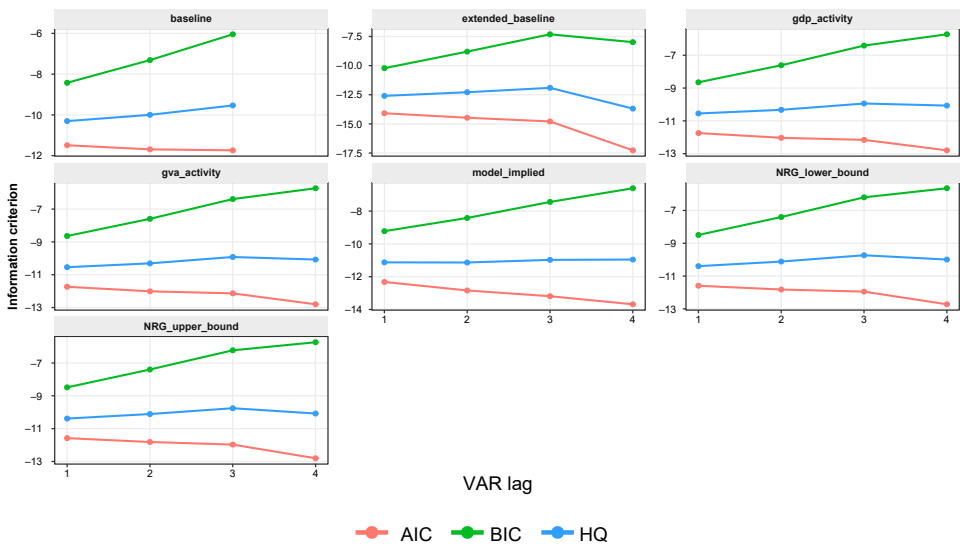


Figure C2. Lag-order selection across SVEC scenarios

Source: author’s analysis.

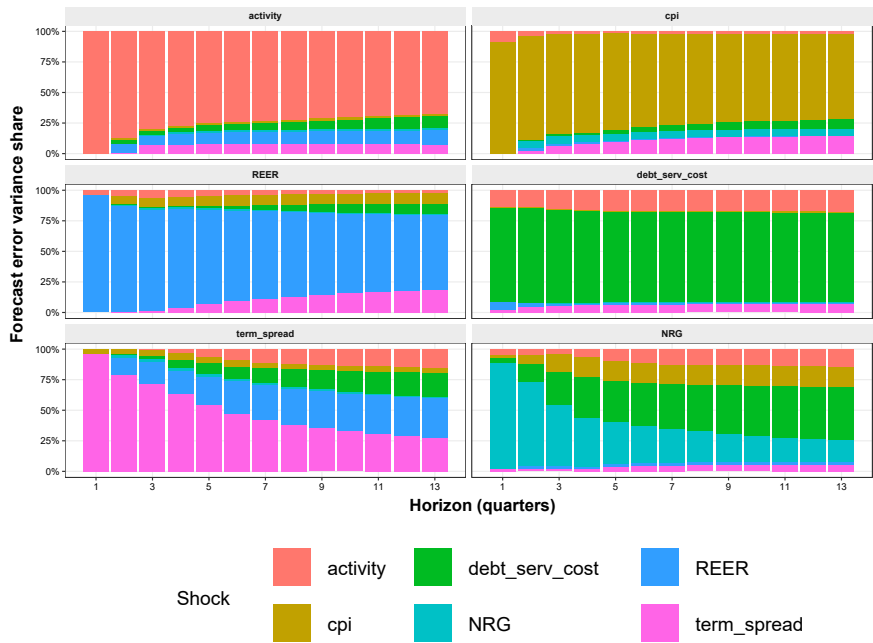


Figure C3. Baseline SVEC FEVD across all identified shocks

Source: author’s analysis.

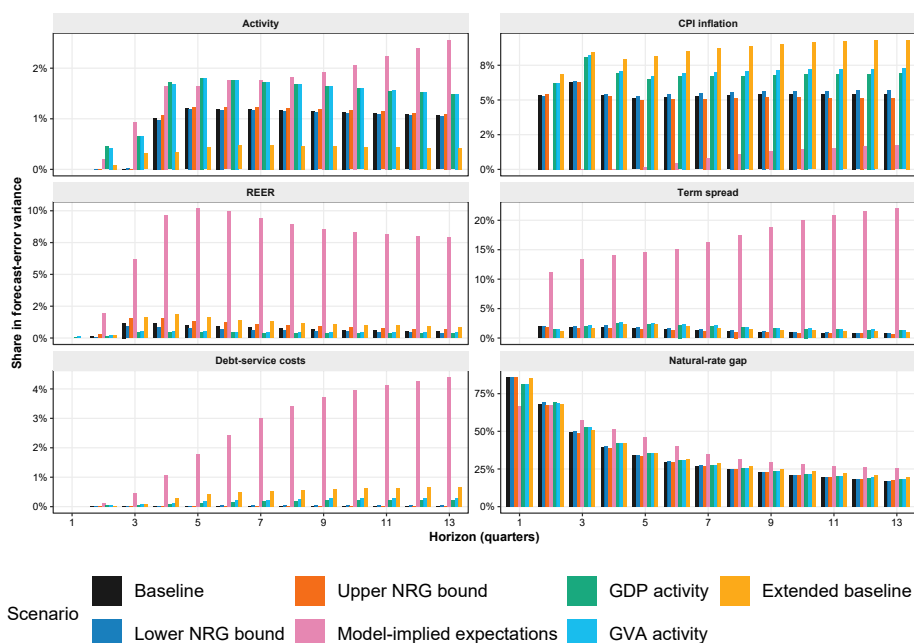


Figure C4. Robust FEVD contribution of the NRG shock across SVEC scenarios

Source: author's analysis.

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Fiscal policy and trade finance in emerging economies: Evidence from Africa

 Andrew Aondohemba Chenge¹

Abstract

The paper examines how fiscal policy shapes trade finance in emerging economies with particular focus on Africa. In the past, the international trade finance market was thought to be liquid and efficient. However, it has recently gone through stressful times, most notably after the period following the 2008 Lehman crisis, necessitating quick structural adjustments. Given that trade finance makes up a growing portion of global trade, developing nations, especially those in emerging market economies in Africa, may be more concerned about its functioning. Nonetheless, a persistent trade finance gap across the continent, regulatory dissonance, exchange rate volatility and macroeconomic instability are just a few of the intricate structural limitations that African economies must contend with. The paper shows that fiscal policy can address trade finance gap through government spending that directly reduces risk for private lenders, and through tax policy that improves the cash flow and profitability of trading businesses, making them more creditworthy. It further reveals that fiscal policy can resolve trade finance constraints through macroeconomic stability and financial sector development.

Keywords

- fiscal policy
- government expenditure
- macroeconomic stability
- taxation
- trade finance

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Introduction

Historically, authorities paid little attention to the global trade finance market since it was thought to be liquid and well-functioning. However, the industry has lately gone through stressful times, most notably following the 2008–2009 Lehman collapse and in late 2011, when funding issues at European banks sparked worries about potential disruptions. Additionally, the industry seems to be undergoing early structural transformation, as seen by the entry of new market players and initiatives to create new modalities that minimise the use of bank resources and balance sheets. However, persistent data inadequacies have made it challenging to monitor and analyse the significance of current market dynamics as well as the magnitude and impact of recent dislocations (BIS, 2014).

The strategies and tools used to finance international trade have recently received more attention in the literature (Ahn, 2011; BIS, 2014; IMF, 2018; Niepmann & Schmidt-Eisenlohr, 2017). Scholars have emphasised the role that shocks to the supply of banks' trade finance services played in the "Great Trade Collapse" that followed the global financial crisis of 2008 (Accominotti & Ugolini, 2020; Ahn et al., 2011; Amiti & Weinstein, 2011; Del Prete & Federico, 2014; Niepmann & Schmidt-Eisenlohr, 2016; Paravisini et al., 2015).

Trade is unquestionably a significant driver of development, but for it to be successful, sufficient funding and support for capacity building are necessary. By bridging the gap between importers' and exporters' divergent expectations regarding when payment should be made, credit and credit insurance help to lubricate trade. For this reason, it is critical to find and fill any funding shortages that may arise. Because importers and exporters are supported by established banking sectors, trade finance is sometimes taken for granted in industrialised nations. Small and medium-sized businesses (SMEs) often have less collateral, guarantees and credit history than larger companies, which makes it difficult for them to obtain finance even in these countries (AfBC, 2025; Ntoya, 2025; World Bank, 2025; WTO, 2016).

Given that they make up an ever-growing portion of global trade, developing nations, especially those in emerging market economies, may be more concerned about trade finance. In addition to unique hurdles including smaller, more selective and sometimes less developed local financial industries, developing countries may have some of the same issues as their developed counterparts, such as creditworthiness recognition. Access to the information and abilities needed to handle trade finance instruments is a major problem in many developing nations. As developing economies look to take advantage of the trade opportunities presented by changing patterns of production, adequate trade finance is crucial (WTO, 2016).

This paper attempts to assess the extent to which fiscal policy shapes trade finance in emerging economies, with particular emphasis on Africa. Specifically, it examines how fiscal policy mechanisms in African countries are tailored to support trade finance. It also evaluates how fiscal policy and trade finance interventions are utilised by African countries to foster macroeconomic growth. Lastly, the paper identifies possible fiscal policy adjustments to restructure the trade finance trajectory in Africa.

1. Conceptual review

1.1. Fiscal policy

Fiscal policy is an instrument by which a government regulates its spending in order to control and influence the economy. Fiscal policy is widely perceived to be linked to growth; more specifically, it is believed that appropriate fiscal policies can be utilised in specific circumstances to boost economic growth and development (Khosravi & Karimi, 2010). Proponents of government intervention in economic activities argue that it can boost long-term growth. They cite the government's role in maintaining efficiency in resource allocation, market regulation, economic stabilisation and social dispute resolution as examples of how the government could use fiscal policy to stimulate economic growth (Mengistu, 2022).

1.2. Trade finance

Trade finance is the oldest form of international finance. Since the beginning of international business, merchants and firms have shown the need for working capital to finance their international commercial operations and have sought ways to lessen the risks associated with long-distance trade. International trade necessitates the immobilisation of significant quantities of cash in a relatively short (but substantial) period of time, as well as the acceptance of significant risks by both exporters and importers. Trade finance refers to all tools and procedures that allow businesses to get capital to fund their international activities and/or decrease the risks associated with international trade (Accominotti & Ugolini, 2020; Asmundson et al., 2011; BIS, 2014).

2. Review of related literature

2.1. Political economy of fiscal policy

The importance of fiscal policy as a policy instrument has fluctuated over time. Laissez-faire, or limited government, was the dominant philosophy prior to 1930. After the Great Depression and the stock market crash, policymakers pushed for governments to get more involved in the economy. Countries had lately reduced the size and influence of government, with markets playing a larger role in the distribution of goods and services. However, many countries reverted to a more active fiscal policy when the global financial crisis threatened to trigger a global recession. Governments can affect the economy through fiscal policy by altering the amount and kinds of taxes, the amount and nature of spending, and the amount and extent of borrowing (CFI, 2019; Horton & El-Ganainy, 2017).

The economy's usage of resources is influenced by governments both directly and indirectly. This is illustrated by the fundamental national income accounting formula, $GDP = C + I + G + NX$, which calculates an economy's production, or GDP, based on expenditures. GDP, or the total worth of all finished products and services generated in the economy, is shown on the left. Private consumption (C), private investment (I), government purchases of goods and services (G) as well as exports less imports (net exports, NX) are the sources of aggregate expenditure or demand on the right. It is clear from this equation that governments have an impact on GDP, controlling G directly and indirectly influencing C, I and NX through changes in taxes, transfers and spending. Fiscal policy that directly raises aggregate demand by increasing government spending is generally referred to as expansionary or "loose". Conversely, contractionary (or "tight") fiscal policy is frequently used if it lowers demand through lower spending (Horton & El-Ganainy, 2017).

Fiscal policy goals differ from one country to another though a major focus shows its objective of delivering goods and services such as basic education, transportation and public safety. Governments may prioritise macroeconomic stabilisation in the short term, which could involve reducing spending or raising taxes to counteract rising inflation or to lessen external vulnerabilities, or increasing spending or lowering taxes to boost a struggling economy. Longer-term goals could include promoting sustainable growth or lowering poverty through supply-side initiatives to enhance infrastructure or education. Even though these goals are generally the same across nations, their relative significance varies based on the specific conditions of each nation. Priorities may change in the short term in reaction to a natural disaster, the business cycle or an increase in the price of food or gasoline globally. Longer-term factors may include endowments of natural resources,

population or development levels. In an advanced economy, pension reforms may target the long-term expenditures associated with an aging population, while in a low-income country, the goal to decrease poverty may cause spending to shift toward primary health care. By reducing procyclical spending, both by avoiding painful cuts when oil prices fall and by limiting spending spikes when they rise, policymakers in an oil-producing nation may seek to better align fiscal policy with broader macroeconomic developments (CBN, 2017; Weil, n.d.).

An excellent case study of fiscal policy is the global crisis that originated from the collapse of the US housing market in 2007. Global economies were impacted by the crisis, since private consumption, investment and foreign trade were all negatively impacted by financial sector issues and declining confidence (all of which affect output, GDP). In response, governments attempted to increase activity through two means: fiscal stimulus, which includes increased discretionary spending or tax breaks, and automatic stabilisers. Stabilisers are not dependent on particular government actions; rather, they take effect when tax income and expenditure levels fluctuate. The business cycle has an impact on how they function. For example, under progressive tax systems, where higher-income earners are placed in higher-tax-rate categories, the amount of taxes collected decreases as output slows or diminishes because company profits and taxpayer incomes decline. During a recession, unemployment compensation and other social expenditures are also intended to increase. Fiscal policy is inherently contractionary during upturns and expansionary during downturns due to these cyclical shifts (Horton & El-Ganainy, 2017; TPC, 2024a, 2024b).

The size of the government is correlated with automatic stabilisers, and advanced economies typically have larger governments. Since both strategies lessen the consequences of a downturn, there may be less need for stimulus in areas with larger stabilisers. Examples of these strategies include tax cuts, subsidies and public works initiatives. In fact, nations with bigger stabilisers tended to use fewer discretionary measures during the most recent crisis. Furthermore, automatic stabilisers are not impacted by implementation delays like discretionary measures are, even though the latter can be adjusted to stabilising requirements. (For instance, designing, obtaining approval and implementing new road projects can take time). Moreover, automatic stabilisers – and their effects – are automatically withdrawn as conditions improve. Designing and implementing stimuli successfully can be challenging, and when conditions improve, they can be challenging to reverse. But in many developing market and low-income nations, stabilisers are comparatively weak due to institutional constraints and limited revenue bases. Even in nations with bigger stabilisers, there might be an urgent need to make up for the lost economic activity and strong arguments for directing the government's crisis response toward the people who are most in need (TPC, 2024a, 2024b; Weil, n.d.).

2.2. How does fiscal policy shape trade and trade balances?

Fiscal policy's direct effect on the balance of payments makes it easy to understand how it influences trade. If fiscal policy refers to the relationship between government spending and tax revenues, and "balance of payments" refers to the current account balance (merchandise trade plus net services and investment income), then the following is true: increasing government spending will substantially increase the current account deficit while maintaining constant revenues and net private saving (private saving less private investment). It follows that unless net private saving increases, the current account deficit (capital inflows) cannot decrease without a commensurate (but causative) decrease in the budget deficit. If accommodating capital inflows are only accessible at a higher interest rate, the increase in net private saving could occur at the same time as a recession and the collapse of private investment (Linn & Wetzel, 1990; Makin, 1989).

Normally, a regime of fixed exchange rates would be used to explore the relationship between fiscal policy (tax and spending) and the balance of payments. Domestic interest rates would experience early upward pressure from more expansionary fiscal policy. At a given global interest rate, capital inflows support fiscal expansion in a Mundellian small-country world with indefinite capital mobility. In the absence of monetary accommodation by the central bank or an endlessly elastic (with regard to interest rates) money demand schedule, the "crowding-out" that leads to a closed-economy setup does not lessen the positive influence on aggregate demand. In the fixed exchange-rate scenario, fiscal expansion has no net effect on the balance of payments, but this conceals a shift in its constituent parts. Unless there is a shift in private net saving or government intervention in foreign exchange markets, the increased capital inflow will be matched by an increase in the current account deficit. In other words, a greater current account deficit is a result of a capital inflow from outside that supports an increase in national dissaving (Dean et al., 2020; Makin, 1989).

As long as the higher interest rate does not increase net private saving by precisely the same amount as the increase in government dissaving, a portion of the capital inflow may come from official intervention in the foreign exchange market intended to peg the exchange rate if private capital is not infinitely mobile. The demand for foreign currencies will be excessive if net private saving growth falls below that key threshold and private capital inflows are insufficient to offset the increase in national dissaving. According to Lane and Perotti (1998), in the event where the exchange rate is completely flexible, the currency depreciates until the sum of increased interest rates and currency depreciation raises net private saving by the same amount as the increase in government dissaving.

On the other hand, if the exchange rate is fixed, government support for the domestic currency will either decrease the amount of money in the country or increase the amount of money in other countries if it is not sterilised. This puts all of the adjustment pressure on the interest rate, which needs to rise domestically by enough to raise capital inflows and private net saving by the same amount as the increase in government dissaving. Capital inflows are improved when the foreign interest rate declines. By boosting imports and decreasing exports, higher domestic prices and lower foreign prices aid in the adjustment by increasing the amount of capital inflows that are needed. Reduced costs overseas may reduce net private saving overseas through the real balance effect on saving, while higher prices at home may also increase private net saving domestically. The adjustment process cannot function if the intervention used to fix the exchange rate is sterile. When the home country's excess demand for foreign exchange becomes chronic, intervention persists until the possibility of a drastic adjustment – typically a devaluation by the deficit country – is realised. At that point, a combination of higher interest rates and currency devaluation results in either the necessary reduction or net private dissaving (Dean et al., 2020; Makin, 1989).

2.3. Trade finance and macroeconomic growth

Prior to the 2008–2009 global financial crisis, politicians, scholars and economic analysts paid comparatively little attention to the function of trade finance in international trade. As a means of maintaining export and import capacity, trade finance did receive high priority in the coordinated restructurings during the debt crisis in the 1980s. Conversely, during the emerging market (EM) financial crises of the 1990s and early 2000s, trade finance was frequently treated with less involvement, which led to a steep decline in trade finance. The IMF came to the conclusion that these contractions made the economic effects of previous crises worse and that, should there be another crisis in the future, trade finance support measures should be explicitly taken into account as part of the broader stabilisation plan (IMF, 2003).

However, starting in 2008, anecdotal evidence indicated that the resulting decline in trade flows could be significantly influenced by disruptions in the supply of trade finance (Amiti & Weinstein, 2011), especially in the wake of the Lehman collapse. In fact, the G20 leaders called for coordinated public sector initiatives to increase the availability of trade finance after worries over a perceived lack of trade finance prompted business and the public sector to work together to better the statistics on trade finance markets. The World Bank Group and the regional development banks significantly increased their assistance to the industry as part

of this endeavour, mostly through guarantee programs. Additionally, the central banks of Brazil and Korea launched creative programs that directly targeted trade finance markets (BIS, 2014).

In fact, trade volumes shrank by a factor of four in the 12 months that ended in March 2009, which was far quicker than the global GDP in 2008–2009. Some have interpreted the significant relative decline in trade as proof that the so-called “Great Trade Collapse” was caused by factors other than a worldwide recession. However, one of the main challenges in assessing the impact of changes in trade finance on global trade flows is the lack of reliable data. Furthermore, the slow-down in trade that was seen in 2008–2009 and 2011 was caused by a number of other factors, including the price and demand for traded commodities; these factors may have had a much greater impact on trade flows than shifts in the availability of trade finance. Naturally, they may have played a role in any reported decline in trade finance to the degree that they decreased demand for trade finance (Baldwin, 2009).

Analysts from the public and private sectors have tackled these issues in a number of ways, such as by conducting surveys, extrapolating from case studies where more comprehensive firm-specific export and financial data are available, or estimating the impact of fluctuations in the availability and use of trade finance using proxy data. They have also made an effort to measure the degree to which the reported decline in international trade flows within a specific timeframe may have been explained by other causes. According to literature, the primary cause of the dramatic decline in global trade volumes in the quarters after Lehman’s bankruptcy was the decline in demand for consumer durables and capital goods worldwide, with trade finance disruptions playing a secondary but economically significant role. Similar findings were reached by the Group’s statistical investigations. Even a secondary contributory role, however, suggests an economically substantial impact on trade and economic activity given the size of the decline in trade volumes (BIS, 2014, 2016).

3. Methodology

A mixed-methods approach was employed as the research design for the study. To obtain a more thorough grasp of a research subject, mixed methodology combines the collection and analysis of both quantitative and qualitative data in a single study. In order to capitalise on the advantages of both quantitative and qualitative data, it integrates both to provide a more comprehensive picture than either approach could accomplish independently. The intentional integration of findings

during collection, analysis or reporting is a component of this method, which goes beyond merely collecting both kinds of data (Creswell & Plano Clark, 2023; Niglas, 2023; Plano Clark & Ivankova, 2016).

Documentary sources were used for data collection. Payne and Payne (2004) as well as Mogalakwe (2006) describe these sources as written documents in the private or public domain containing relevant information that can be utilised by researchers. Thus, data was derived from reports of international organisations such as the African Export-Import Bank (Afreximbank), African Development Bank (AfDB), Financial Sector Deepening (FSD) Africa, Bank of International Settlements, International Monetary Fund (IMF), World Trade Organization (WTO), International Trade Centre (ITC) and International Chamber of Commerce (ICC).

Data analysis was done using content analysis. Content analysis is a research technique that methodically examines and detects communication patterns. It entails categorising the data into easily understood categories, or “codes”, in order to quantify the occurrence of specific phrases, themes or concepts, allowing for conclusions about the message, its sources and context. The procedure is frequently systematic and replicable, incorporating qualitative and quantitative methods (Bailey, 2008; Bengtsson, 2016; Berg, 2001; Burnard, 1991, 1995).

4. Data presentation and analysis

4.1. State of fiscal policy indicators in Africa

Despite the challenges posed by the global economic slowdown, African growth has persevered. Due to supply chain difficulties and geopolitical tensions, global consumption was muted in 2024, which had a detrimental impact on African exports, particularly in primary commodities. Africa’s internal growth has been hindered by political instability in Sudan, terrorism in the Sahel and conflicts in the Democratic Republic of the Congo. Significant droughts in Somalia and the Sahel as well as cyclones in Comoros, Madagascar and Mozambique are examples of climate-related problems that have further hampered economic prospects (Afreximbank, 2025a). In spite of these obstacles, the continent’s growth has risen (although marginally) increasing from 3.3% in 2023 to 3.4% in 2024. While this growth rate is still below 2022 estimates, it is higher than pre-pandemic 2019 numbers, suggesting some recovery despite persistent challenges (Figure 1).

Although net exports have a negative impact on overall performance, strong household spending is what drives Africa’s resilience on the demand side. Resilient

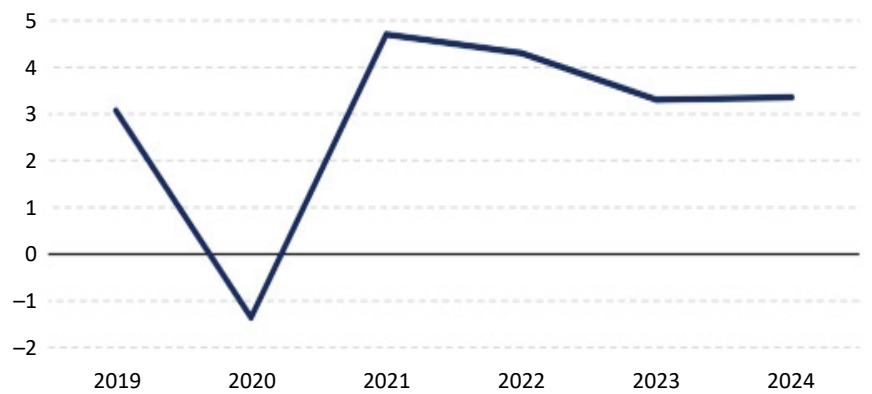


Figure 1. Africa’s real GDP growth, 2019–2024 (in %)

Source: (IMF, 2024; Afreximbank, 2025a).

household consumption increased its GDP growth contribution from 1.8 percentage points in 2023 to 2.7 percentage points in 2024. Investment contributions decreased from 2.0 percentage points to 1.8 percentage points. After declining by –0.1 percentage point in 2023, public spending increased by 0.2 percentage points. Nonetheless, net export stagnation remains a major obstacle, accounting for –0.8 percentage points of growth in 2024, up from –0.2 percentage points the year before (Figure 2).

The supply-side resilience of African economies was supported by a strong services sector. Between 2023 and 2024, the services sector made up about 2.3% of the total. On the other hand, the industrial sector saw a minor contraction, reduc-

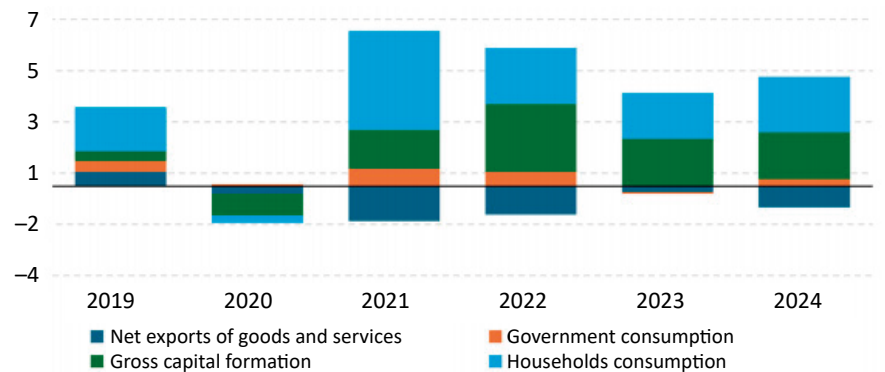


Figure 2. Demand-side decomposition of Africa’s GDP growth, 2019–2024 (in %)

Source: (World Bank, 2024; IMF, 2024; Afreximbank, 2025a).

ing its share of economic growth by 0.1 percentage point from 2023 to a revised 0.5 percentage point contribution. Although the agricultural sector still faces difficulties as a result of climate disruptions, its growth contribution has improved slightly, rising from 0.27 percentage points in 2023 to 0.33 percentage points in 2024 (Figure 3).

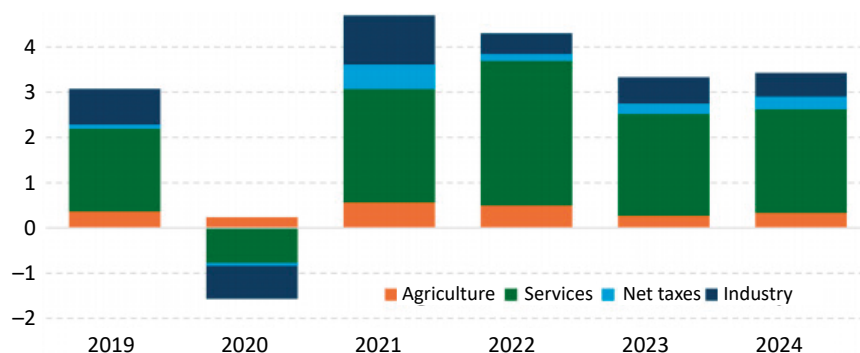


Figure 3. Sectoral decomposition of Africa's GDP growth, 2019–2024 (in %)

Source: (World Bank, 2024; IMF, 2024; Afreximbank, 2025a).

Although the current account deficit has been growing, it is still less than it was before the pandemic. It dropped to less than 2% of GDP between 2021 and 2023 as a result of increased commodity costs. But in 2024, it increased to 2.4% of GDP as import prices remained high and global commodity prices declined (Afreximbank, 2025a). African nations' dependence on imports, lack of export diversification as well as volatility in commodity prices are the main causes of the continent's structural imbalance.

Current account analysis demonstrates that fiscal deficits have a major impact on the evolution of the continent's net external position. While net private savings have stayed almost unchanged, Africa's current account deficit has increased in 2023 and 2024 as a result of a growing budget deficit. This increase implies that government expenditure raises domestic demand, which is met by imports rather than domestically produced goods and services, thus adding to budget deficits (Figure 4).

Furthermore, chronic budget deficits that have persisted for several decades are to blame for the rise in sovereign debt throughout Africa. This position is made worse by low national savings mobilisation and underdeveloped domestic financial markets, which lead to long-term account deficits. The average fiscal balance of the continent has continuously been in deficit during the last 20 years. The one exception, which occurred from 2005 to 2008, was brought on by an oil boom that greatly increased government revenue. The year 2006 saw the largest fiscal surplus, amounting to almost 4% of GDP. The worst public deficit-to-GDP

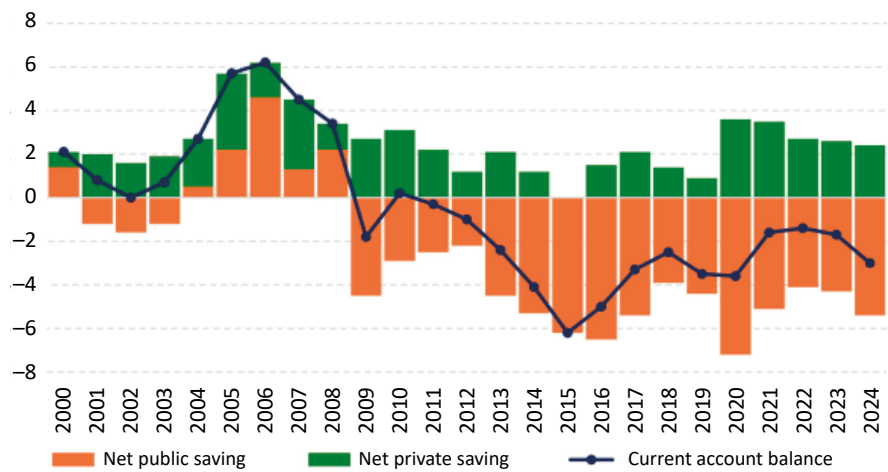


Figure 4. Current account decomposition, 2000–2024 (% of GDP)

Source: (IMF, 2024; Afreximbank, 2025a).

ratio, however, occurred in 2020 as a result of fiscal measures to the COVID-19 pandemic, rising to 5.37%. Over the past 20 years, the current account balance has continued to be negative. Given the increasing oil prices, the current account deficit was at its lowest in 2007 (0.19% of GDP). The current account deficit, on the other hand, peaked in 2015 at 7.27% of GDP during the decline in oil prices from 2014 to 2016 (Figure 5).

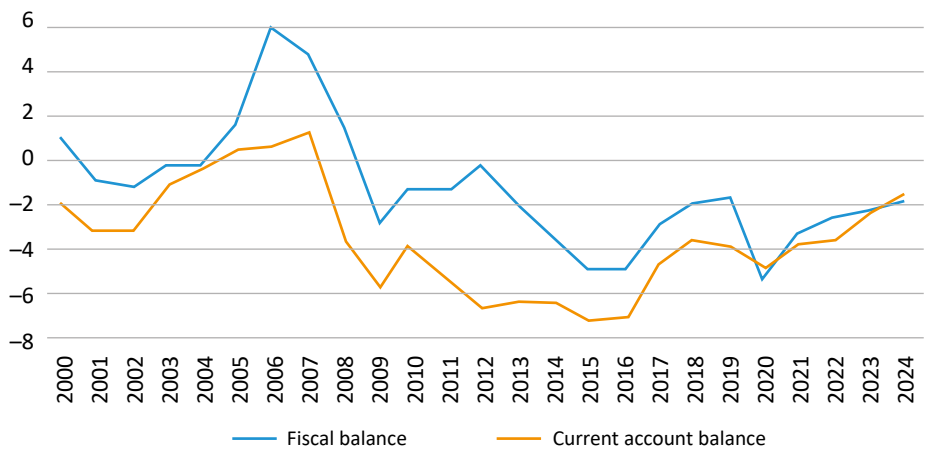


Figure 5. Fiscal balance and current account balance, 2000–2024 (% of GDP)

Note: Data are averages over African countries for each year.

Source: (IMF, 2024; Afreximbank, 2025a).

The twin deficit hypothesis – a positive causal relationship between the fiscal balance and the current account balance – is supported by empirical studies conducted in Africa between 2000 and 2023. The data indicates that the current account deteriorates by 0.27% of GDP in the year of the shock and by 0.28% in the subsequent year when there is an exogenous fiscal deficit equal to 1% of GDP (Afreximbank, 2025a). Short-term negative effects are not always associated with the twin deficits. The importation of investment goods required for public infrastructure projects is likely to worsen the external balance in the short term if these investments cause fiscal deficits in African nations. But over time, the productivity benefits brought about by these expenditures ought to boost growth rates and improve the current account balance.

4.2. Landscape of trade finance in Africa

An era of structural readjustment has begun in the global economy. Rising economic nationalism, supply chain disruptions and rapid digitalisation have all started to reshape trade and investment since the global financial crisis of 2008. According to a Deutsche Bank (DB) study (cited in Afreximbank, 2025b), semiconductor chips already made up around 15% of the value of global goods trade in 2020, while crude oil, the barometer of merchandise commerce, has been surpassed by semiconductors. Since the 2008 financial crisis, services have grown from 20 to 25% of global trade, with their true size still being underrepresented in official figures. This growth has been fuelled by the growing usage of digital platforms as necessary to enable remote personal, corporate and professional transactions. Additionally, the geography of trade has changed. As shown in Table 1, Europe, North America as well as East and Southeast Asia collectively accounted for 75% of global exports in 2023, demonstrating that these three regions – dubbed “global factories” (Baldwin & Lopez-Gonzalez, 2015) – continue to have a dominant position.

Due to a global financial and trade environment that is experiencing significant change, Africa finds itself at a critical juncture in its economic development. Global value chains have been more frequently disrupted in the last ten years, international trade governance has been more fragmented, and the trend toward digital and green finance has accelerated. With major ramifications for Africa’s capacity to obtain finance, expand its economies and engage in competitive international trade, these developments are rewriting the norms of investment and commerce.

The round-tripping model, which has caused massive foreign exchange reserve leaks and ongoing balance of payments pressures, has continued even as Africa’s trade direction has shifted eastward (Asia), demonstrating the stickiness of the colonial development model of resource extraction, where African countries sys-

Table 1. Share of regions in global exports

Regions	Services		Goods		Goods and Services	
	2009	2023	2009	2023	2009	2023
Africa	2.2	1.8	3.5	3.2	2.9	2.3
European Union	38.4	38.2	33.9	30.4	34.9	32.3
United Kingdom	8.0	7.4	2.8	2.2	4.0	3.5
Total Europe	46.3	45.6	36.7	32.5	38.9	35.8
China	4.0	4.9	9.5	14.2	8.3	11.9
Hong Kong	1.8	1.2	2.6	2.4	2.4	2.1
South Korea	2.0	1.6	2.9	2.7	2.7	2.4
Taiwan	0.6	0.7	1.6	1.8	1.4	1.5
Japan	3.3	2.6	4.6	3.0	4.3	2.9
ASEAN nations	4.9	6.8	6.5	7.6	6.1	7.4
Total East and Southeast Asia	16.4	17.8	27.8	31.7	25.2	28.3
India	2.6	4.3	1.3	1.8	1.6	2.4
United Arab Emirates	0.3	2.1	1.5	2.0	1.2	2.1
Qatar	0.1	0.4	0.4	0.4	0.3	0.4
Total Other Asia	2.9	6.8	3.2	4.3	3.1	4.9
United States	13.9	12.7	8.4	8.5	9.6	9.5
Mexico	0.6	0.7	1.8	2.5	1.5	2.0
Canada	1.9	1.7	0.5	0.6	0.8	0.9
Total North America	16.4	15.1	10.8	11.5	12.0	12.4
Total (trillion)	3,603	7,822	12,585	23,813	16,188	31,635

Source: (Afreximbank, 2025b).

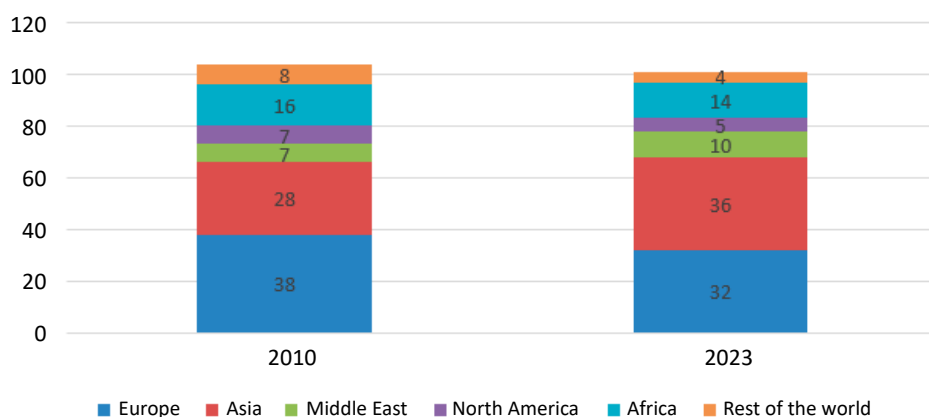


Figure 6. African origin of imports, 2010 and 2023 (in USD billion)

Source: (Afreximbank, 2025b).

tematically exported raw materials and natural resources to European powers and imported value-added manufactured goods at higher prices (Figure 6). The most recent projections indicate that hydrocarbons account for the majority of Africa's trade, with refined petroleum and allied products accounting for the largest share of the continent's overall imports (ITC, 2023).

Beyond the massive leaks of foreign exchange reserves, the colonial growth model exposes nations to frequent negative commodity terms of trade shocks, which are substantially to blame for the high frequency of balance of payments crises and the unstoppable increase in external obligations. Additionally, in a world of global value chains, where manufactured and intermediate commodities with rising technology content dominate trade, African trade has steadily declined in comparison (Fofack, 2024; Luke, 2023; Wellisz, 2022). Although its proportion of the world's population has continuously climbed to 17%, the region today makes up less than 3% of global trade, down from roughly 5% in the years following independence (Figure 7). Additionally, intra-regional trade has remained a paltry 15% of overall African trade, compared to 60% in Asia and 70% in Europe, causing the distribution of African trade to be biased towards extra-African trade (Figure 8).

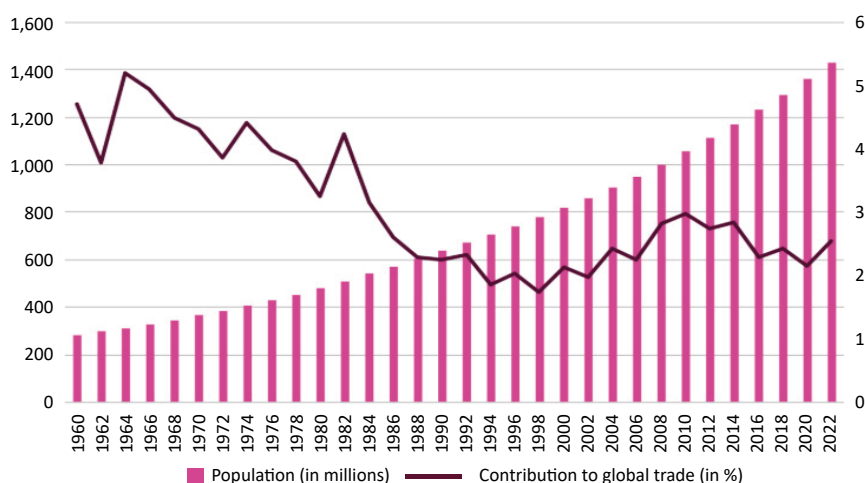


Figure 7. Africa's population (left axis) and contribution to global trade (right axis), 1960–2022

Source: (UNDESA, 2022; UNCTAD, 2023; Fofack, 2024).

Due to protectionist policies, geopolitical tensions and unfavourable commodity terms of trade shocks, Africa's share of global exports has decreased from 3.5% in 2009 to 3.2% in 2023, highlighting its marginal position in global value chains. Africa's involvement in high-value industries is restricted by the disruption of supply chains caused by the competition between the US and China for semiconduc-

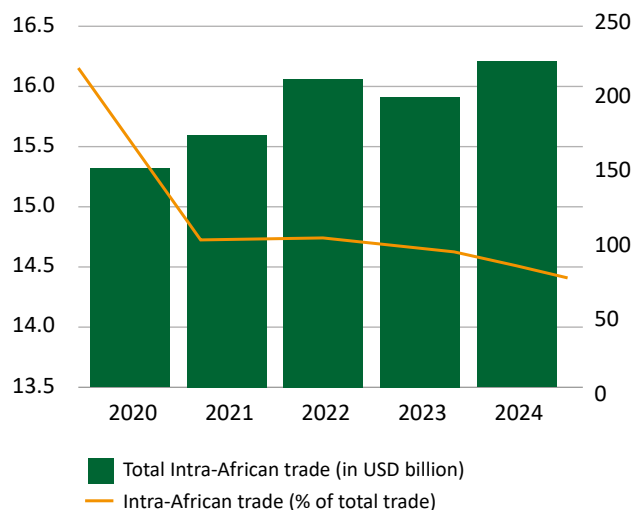


Figure 8. Total African trade (right axis) versus total intra-African trade (left axis), 2020–2024

Source: (IMF, 2025; Afreximbank, 2025b).

tors and vital minerals. African exports are under potential threat due to global protectionism, which includes US tariffs and the European Union’s Carbon Border Adjustment Mechanism. Global attention is drawn to Africa’s abundant reserves of vital minerals like cobalt and lithium, but collaborations run the risk of sustaining exploitative paradigms with little local value addition (Afreximbank, 2025b). To improve resilience and lessen dependency on unstable international markets, it is crucial to invest in infrastructure and digital finance as well as to strengthen African-led value chains through the creation of the African Continental Free Trade Area (AfCFTA).

The AfCFTA has the potential to drastically alter the continent’s trade and economic environment. It creates one of the world’s largest free trade areas, with 1.4 billion people and a combined GDP of USD 3.4 trillion (Fofack, 2021; 2024; Signé, 2023). It has been hailed as a game-changer because it has the potential to boost investment flows, which would then shift their composition and direction from natural resources to labour-intensive manufacturing as businesses benefit from economies of scale, competitiveness and productivity gains brought about by the sharp decline in the risk of investing in smaller markets. The AfCFTA is predicted by the World Bank to increase Africa’s exports to the rest of the world by 32% by 2035 and stimulate foreign direct investment, which is projected to rise by 111% to 159% (World Bank, 2020). Leveraging its enormous potential to go beyond the resource-extraction-based colonial development model will help to speed up the

diversification of growth and export sources, launching the region into a positive feedback loop of strong economic growth and a wider tax base that will fortify Africa's fiscal and debt sustainability foundation.

4.3. Trade finance gap in Africa

Africa has an annual trade finance gap of approximately \$100 billion. As 80 to 90% of businesses on the continent are small and medium-sized, this significantly restricts their capacity to participate in regional trade. Due to a predisposition towards external markets, just 18% of African banks' trade finance portfolios facilitate intra-African commerce. Small and medium-sized businesses are unable to expand their operations and incorporate themselves into local value chains due to this deficiency, which is made worse by high borrowing rates and tight international banking regulations like Basel IV. Closing this gap is critical to the success of the AfCFTA, which was intended to increase intra-African trade. To fully realise the potential of the continental accord, measures like Pan-African Payment and Settlement System (PAPSS) as well as Afreximbank's \$17.5 billion trade finance disbursements are important first steps, but expanding access to reasonably priced credit and harmonising financial laws are also top goals (Afreximbank, 2025b).

Trade finance accounts for over 80% of global trade, however the distribution is not uniform. One of the top three export hurdles cited by businesses in low-income regions is the inability to obtain finance. A report from the African Development Bank and Africa Import-Export Bank used exclusive data from over 600 banks across 49 African countries between 2011 and 2019 to illustrate this constraint. The report titled "Trade finance in Africa: Trends over the past decade and opportunities ahead" provides an overview of the trade finance gap in Africa during the last ten years, along with the variables that have influenced its development (AfDB-Afreximbank, 2020).

The trade finance gap shrank gradually but consistently from an estimated US\$120 billion in 2011 to US\$70 billion in 2016. However, in 2016, the downward trend in unmet demand was reversed, and since then, there have been some little variations. The predicted trade finance gap for 2018–2019 was still large compared to what the region's proportion of global trade would indicate, even though it was less than the nine-year average of US\$91 billion. A conservative estimate of the unmet demand for trade credit in 2019 was around US\$82 billion (Figure 9). Unmet trade financing demand in Africa accounted for over 8% of the region's total trade value and 5.5% of the global trade finance gap in 2019, with the continent's merchandise trade and global trade finance gap estimated at US\$1 trillion and US\$1.5 trillion, respectively. Africa's contribution of the global trade finance

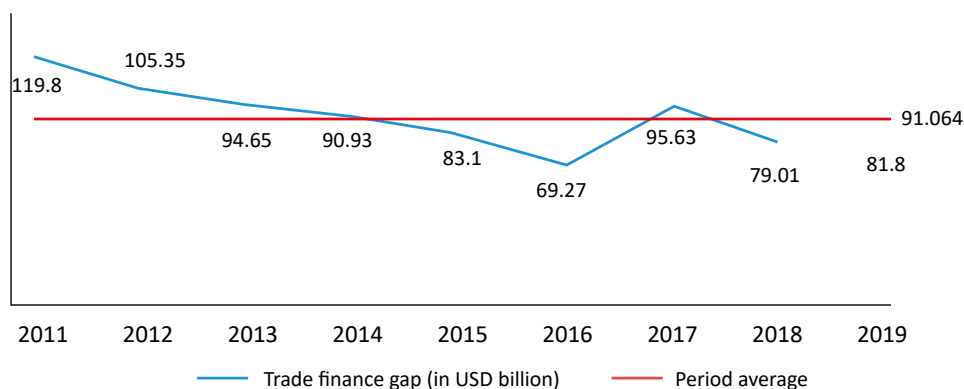


Figure 9. Trade finance gap in Africa, 2011–2019

Source: (Nyantakyi et al., 2021).

gap is disproportionately bigger than the region's share of worldwide trade, despite the fact that 5.5% may seem low at first (Nyantakyi et al., 2021). This is because Africa's trade only makes up 3% of global trade.

An examination of the global policy framework that has influenced the trade finance environment in Africa and beyond since the global financial crisis is necessary to comprehend the development of the trade finance gap in the region. It is possible that the global policy reaction to the Great Trade Collapse contributed to the reduction of the trade finance gap in Africa between 2011 and 2016. First, the gradual but consistent decline in the trade finance gap from 2011 to 2016 was a result of increased awareness of unmet demand after the 2008 global financial crisis. The global financial crisis of 2008–2009 saw a sharp and coordinated decline in global trade. Evidence suggests that trade credit issues were the second most important factor in the Great Trade Collapse, behind the decline in demand. However, whereas North America and Europe recovered swiftly, Africa and, to a lesser extent, Eastern Europe continued to face credit difficulties. In fact, in mid-2009, the only continent still facing dwindling trade finance supplies was Africa.

A prompt and comprehensive policy response was implemented to support trade credit for developing economies. Over US\$80 billion was made available to assist international trade through the establishment of US\$9 billion in trade finance facilities by major multilateral development banks (MDBs). In order to ensure that trade transactions between Western firms and their African counterparts had the financial resources required to make trade contracts viable, large commercial banks like Sumitomo Mitsui Banking Corporation (SMBC) of Japan also implemented measures to help close the gap by using “follow your firm” strategies, in which foreign banks followed their domestic firms (Mora & Powers, 2009; Nyantakyi et al., 2021). The International Finance Corporation, African Development Bank and

Asian Development Bank all have trade finance support facility programs that continue to this day, demonstrating that MDB interventions have continued long after the global trade collapse. These initiatives, which have supported the region's trade finance supply, have primarily benefited African banks.

Between 2011 and 2016, the drop in commodity prices contributed to an exogenous downturn in the demand for trade finance. African trade fell by an average of 6% a year between 2012 and 2016, and the trade finance gap shrank by almost 10% throughout that time. In fact, due primarily to the drop in commodity prices that started in mid-2015, the entire value of African trade in 2016 was at its lowest point, at almost US\$848 billion. Not unexpectedly, the trade finance gap was at its lowest that year, at US\$69.3 billion (Figure 9). The decline in African trade value led to an exogenous reduction in the continent's total demand for trade finance, hence narrowing the imbalance between supply and demand.

Nonetheless, the trade finance gap may have increased recently due to shifts in the regulatory environment. In 2017, the downward trend in the global trade finance gap reversed. This reversal was certainly not unique to Africa; rather, it was symptomatic of the worsening global trade finance environment. According to recent data released by BNY Mellon and ADB, trade finance rejection rates are rising globally, which explains the gap. Three out of four banks cite KYC and compliance issues as the main reasons for rejection (BNY Mellon, 2019). The trade finance gap naturally widens with a larger rejection rate. In this case, the 2016 increase in the gap can be a result of the shifting global banking regulatory landscape. Banks are avoiding the trade finance industry, and international correspondent banks that are vital to African trade are pulling out of the continent as African nations embrace the new Basel III banking regulations that have gone into effect, particularly the way that Basel III treats trade finance as a riskier asset class (Table 2 and Figure 10).

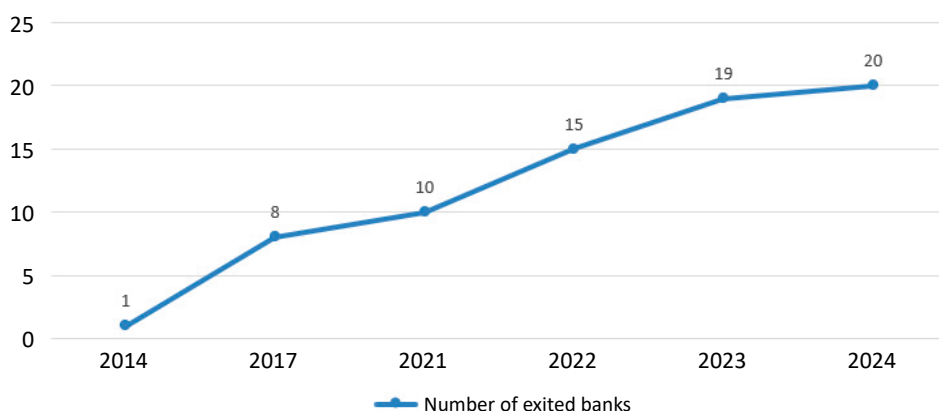


Figure 10. The exit of international banks from Africa, 2014–2024

Source: (Afreximbank, 2025c).

Table 2. Cumulative increase in the number African countries affected by international bank withdrawal announcements

Year	Banks	Newly affected African countries	Cumulative total (African countries)
2014	Citi Bank	Egypt	Egypt
2017	Barclays Plc	Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia	Egypt, Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia
2021	Atlas Mara	Mozambique, Rwanda, Tanzania, Botswana, Zambia	Egypt, Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia, Mozambique, Rwanda
2022	Credit Suisse & Standard Chartered	Angola, Cameroon, Gambia, Sierra Leone, Zimbabwe	Egypt, Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia, Mozambique, Rwanda, Angola, Cameroon, Gambia, Sierra Leone, Zimbabwe
2023	Societe Generale	Congo, Equatorial Guinea, Mauritania, Chad	Egypt, Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia, Mozambique, Rwanda, Angola, Cameroon, Gambia, Sierra Leone, Zimbabwe, Congo, Equatorial Guinea, Mauritania, Chad
2024	HSBC & BNP Paribas	South Africa	Egypt, Botswana, Ghana, Kenya, Mauritius, Seychelles, Tanzania, Zambia, Mozambique, Rwanda, Angola, Cameroon, Gambia, Sierra Leone, Zimbabwe, Congo, Equatorial Guinea, Mauritania, Chad, South Africa

Source: (Afreximbank, 2025c).

The number of banks involved in trade finance activities has decreased in Africa as a result of stricter Basel III capital requirements on trade finance assets and new anti-money-laundering/know-your-client (AML/KYC) compliance measures that have led to lower margins and higher due diligence costs. Table 2 and Figure 10 show that the percentage of African banks that provided trade finance dropped from 92% in 2014 to 71% in 2019 – a 21% drop – and then continued to decline in 2024. Higher costs and lower margins have reduced the profitability of minor transactions for banks that have stayed in the trade finance industry, particularly for small banks with higher average expenses. As a result, the supply of trade finance has decreased and rejection rates have increased, especially for SMEs.

It was once believed that SMEs' weak creditworthiness was the cause of their higher-than-normal trade finance rejection rate. However, a peculiar aspect of recent SME trade finance activity is that, although the risk profile for SME trade finance in Africa has improved, with the default rate dropping from 14% in 2014 to 10% in 2019, the rejection rate for SME trade finance applications has increased from 21% to 40% during the same period, indicating that there is more to the

SME trade finance rejection rate than just low creditworthiness. Correspondent banking connections are also affected by regulatory challenges. Due to increasingly strict AML/KYC rules and capital requirements, banks that provide the liquidity and risk-mitigation facilities that support international trade are steadily reducing their operations from riskier areas, especially in Africa, as part of a process known as “de-risking”. In 2016, Barclays PLC’s withdrawal from the area was widely reported. In fact, according to Afreximbank (2025c) and Nyantakyi et al. (2021), 20% of African issuing banks see correspondent banking ties as the main barrier to the supply of trade finance.

It is still challenging to forecast how the trade finance gap would develop in the future given the current uncertainty brought up by COVID-19. However, there are concerns that the epidemic would undo some of the gains, if not all of them, and push the trade finance gap above its typical long-term average of US\$91 billion. (Note: The trade finance gap in Africa was estimated at US\$80–US\$120 billion between 2021–2024) (Afreximbank, 2025a, 2025b, 2025c). Banks are hesitant to lend to African businesses as their balance sheets deteriorate as a result of COVID-19-related issues. Even in cases where banks are able to provide trade finance to businesses, the steps implemented to address the pandemic might occasionally make it challenging to conduct these transactions quickly (Afreximbank, 2021, 2025c). Consequently, it is imperative that policymakers keep pooling resources to guarantee that the trade finance imbalance does not rise, at the very least.

4.4. Building a sustainable trade finance ecosystem via robust fiscal policy

A complex network of structural barriers affects African economies, such as regulatory dissonance, currency rate volatility, macroeconomic instability and a persistent trade finance gap that is estimated to be over US\$100 billion yearly. Sovereign debt vulnerabilities, infrastructure deficiencies and systemic biases ingrained in international financial systems – such as biased credit rating practices, restricted access to concessional finance and underrepresentation in international decision-making bodies – complement these limitations (Afreximbank, 2025b). These difficulties do not require retreat. They call for coordination, leadership and fiscal reform.

The World Bank Group claims that liberal trade policies have helped more than a billion people in various nations escape poverty. Although there could have been more, the trade finance gap has consistently slowed down the productivity of international trade. This is especially true for African nations and companies. The difference between unmet and satisfied demand for trade funding is known as

the “trade finance gap”. Working capital is necessary for trade, whether it takes the form of products or services. The trade finance gap is caused by this capital’s unavailability to all types of firms. The trade finance gap is estimated to be \$2.5 trillion worldwide, with Africa accounting for about \$120 billion of that total (De Rose, 2025; Mwaba et al., 2025).

Professionals and trade specialists have discussed how to bridge the trade finance gap during the past ten years. Trade finance gaps can be addressed by fiscal policy, which is the use of taxes and spending by the government to control the economy. Government expenditures that directly lower risk for private lenders and tax laws that increase trading companies’ cash flow and profitability, as well as increase their creditworthiness, are the main ways it might accomplish this. Fiscal policy can also resolve trade finance constraints through macroeconomic stability and financial sector development (AfBC, 2025; De Rose, 2025; Ntoya, 2025).

1. Direct government spending and risk-sharing: By providing liquidity, reducing risks that the private sector is unable or unwilling to take on, as well as fostering a stable climate for private lending and investment in trade-related industries, direct government expenditure and risk-sharing can improve trade finance. Programs that crowd in private sector funding and absorb high-risk parts of trade transactions can also be funded by governments. These can be accomplished by:
 - A. Export Credit Agencies (ECAs) Funding: Increasing the financial capacity and mission of government-backed ECAs is the most straightforward strategy. ECAs make guarantees using public cash, supplying commercial banks with sovereign guarantees to mitigate the risk of trade loan or credit letter default. This encourages banks to offer trade finance by drastically reducing their risk weight. In addition to providing guarantees, ECAs also employ government funds to offer direct lending and reinsurance, acting as a direct lender or reinsurer for high-value or high-risk transactions that the private sector avoids.
 - B. Establishing and funding trade finance facilitation initiatives: Governments can put money into the trade finance initiatives of regional banks and multilateral development banks (MDBs). Banks in underdeveloped nations receive guarantees from this money, enabling them to validate letters of credit and gain access to the international trade network.
 - C. Investing in regulatory and digital infrastructure: Expenditure on modernising customs procedures, creating a Single Window for trade, and digitising trade documents (such as electronic bills of lading) all cut down on trade time and operational risk, which in turn lowers costs and expands access to finance (AfDB, 2017; Auboin & Meier-Ewert, 2003).

2. Targeted tax incentives: Tax policy can be modified to instantly boost the financial stability and liquidity of businesses that import and export.
 - A. Accelerated Value Added Tax (VAT) reimbursements: A lot of exporters are experiencing cash flow problems while they wait for their inputs' VAT refunds. The exporter's working capital and overall liquidity can be enhanced by a fiscal policy that prioritises the quick processing and payment of VAT refunds, which lessens the need for expensive bank financing right away.
 - B. Tax credits/deductions for trade costs: Allowing for immediate tax deductions for export-related spending or providing tax incentives, such as specific tax credits for R&D or investment in export-related capacity, improves a company's internal cash flow and long-term competitiveness.
 - C. Reducing financial transaction taxes: Businesses' total cost of financing can be directly decreased by lowering or doing away with taxes on particular cross-border financial transactions or trade finance instruments (Owens & Zhan, 2018; Redonda et al., 2020).
3. Macroeconomic stability and financial sector development: Good fiscal management reduces the general impression of risk that fuels the gap by fostering a stable environment in which private finance can flourish.
 - A. Fiscal prudence to stabilise the exchange rate: The danger of inflation and currency instability is decreased by limiting the budget deficit and avoiding excessive public debt. For trade finance, a stable exchange rate is essential because it reduces currency risk, which lowers transaction costs and makes pricing simpler for banks.
 - B. Supporting funding for financial literacy and capacity building: Government investments in initiatives to enhance the financial reporting and governance of SMEs – the group most impacted by the gap – make them appear to commercial banks to be less risky and more transparent borrowers.
 - C. Regulatory alignment (via fiscal budget): Allocating funds to ensure that domestic financial regulations are in line with international standards (such as Basel III) while also providing favourable treatment for short-term trade finance assets can help prevent banks from facing fiscal penalties from their own regulatory body for extending trade credit.
 - D. Public investment in infrastructure: Government expenditure on trade-critical infrastructure, such as ports, new customs procedures and digital trading platforms, reduces the time and non-financial expenses related to trade. This increases the efficiency of the supply chain as a whole, which speeds up and lowers the risk of trade transactions and incentivises banks to offer better conditions for finance (OECD, 2021).

Conclusions

The shifting global and regional financial landscape has the potential to change African trade. Global financial turbulence, trade disputes and evolving patterns of foreign direct investment all pose significant difficulties that could stifle development and create vulnerabilities. However, with fiscal policy reforms that prioritise expedited regional financial integration, combined with transformative initiatives and increased infrastructure expenditures, Africa can create new opportunities for intra-African trade and value chain development. By prioritising fiscal policy reforms and coordinated investments, African countries can drive long-term industrialisation, diversify their economies and eventually boost their competitiveness in an increasingly interconnected global market. This multilayered reorganisation, however complex, provides hope for African states to not only stabilise their trade networks, but also to emerge as an increasingly significant actor in the global economy.

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