World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

LINKING KNOWLEDGE-BASED ECONOMIC INDICATORS WITH FINANCIAL REPORTING QUALITY: AN EMPIRICAL STUDY USING PANEL DATA ANALYSIS

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Article history:

Received: 30th September 2025
Accepted: 28th October 2025

Abstract:

This study examines whether national knowledge assets improve banks' financial reporting quality in four MENA economies Iraq, Saudi Arabia, Egypt, and the United Arab Emirates over 2010–2024. Knowledge intensity is proxied by tertiary enrollment rate, internet users as a share of population, and R&D expenditure as a percent of GDP. Reporting quality is a 0–100 country–year index averaged across resident banks. The empirical strategy uses a cross-sectionally augmented ARDL with Common Correlated Effects to absorb regional shocks and allow heterogeneous short-run dynamics under pooled long-run parameters. Diagnostics confirm cross-sectional dependence in raw series, stationarity consistent with mixed I(0) and I(1) orders, and well-behaved residuals after CCE. Bounds testing indicates cointegration. Long-run coefficients are economically meaningful β_Tertiary 0.180 p=0.001 β_Internet 0.220 p<0.001 β_R&D 4.100 p=0.010. The error-correction speed is −0.470 p<0.001 implying rapid convergence. Short-run effects are positive and smaller ΔTertiary 0.050 p=0.012 ΔInternet 0.080 p=0.001 ΔR&D 0.900 p=0.047. Country heterogeneity shows faster adjustment in Iraq and stronger short-run impacts in the United Arab Emirates while Saudi Arabia and Egypt sit between. Results answer the research question in the affirmative and support hypotheses that human capital, connectivity, and innovation effort act as structural determinants of reporting quality. Banking implications are direct invest in professional pipelines, broadband quality, and applied analytics and integrate model governance and data standards to lift disclosure reliability and timeliness. Supervisors should scale SupTech for peer benchmarking and anomaly detection and mandate machine-readable publication and common data dictionaries. The evidence indicates that knowledge-based development is also disclosure policy and strengthens the informational foundations of banking.

Keywords: knowledge-based economy, financial reporting quality, banking, CS-ARDL, MENA

INTRODUCTION

The nexus between the knowledge-based economy and financial reporting quality in banking warrants systematic examination in Middle East and North Africa settings. Four economies are analyzed Iraq, Saudi Arabia, Egypt, and the United Arab Emirates over 2010–2024. The knowledge base is proxied by three system-level indicators that capture complementary channels into reporting practice tertiary enrollment rate human capital formation, internet users share digital connectivity, and R&D expenditure percent of GDP national innovation effort. Financial reporting quality is measured by a ready-to-use 0–100 index averaged across resident banks at the country–year level to reflect reliability, timeliness, and decision usefulness. This design responds to the field's maturation toward measurable constructs and cross-country comparability, as documented by bibliometric mapping and indicator standardization in knowledge-economy research and integrated reporting work that links innovation, governance, and disclosure under uncertainty (Aparicio, Iturralde, & Rodríguez, 2023; Erokhin et al., 2024). The research question is straightforward do deeper

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Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

knowledge assets translate into higher-quality bank reporting once country and time effects and common shocks are controlled. The regional context provides heterogeneous trajectories in IFRS adoption, regulatory reform, and digital diffusion, enabling credible identification of both long-run relations and short-run adjustments. The horizon includes multiple policy cycles and technology waves, improving variance for inference and external validity for banking systems in emerging markets.

The choice of constructs and the stimulation of the causal structure is supported by the previous literature. When the accounting information quality mediates the relationship, knowledge management processes increase the business performance, and it signifies a measurement and assurance channel between knowledge assets and outcomes (Al-Dmour, Zaidan, and Al Natour, 2023). It is demonstrated in the intellectual capital literature that the human, structural, and relational indicators are prioritized in the knowledge industries and justify the use of human capital and innovation proxies to assess macro-to-firm transmission (Mehralian, Rasekh, Akhavan, and Ghatari, 2013). The literature on work in emerging markets records the complementarities between the financial development and knowledge pillars, suggesting that the discipline of disclosure is increased with the market depths and the size of digital infrastructure (Low, Tee, Kew, and Ghazali, 2015). The studies of the GCC and the MENA region as a whole point to policy shifts away in oil-focused to knowledge-based economic development with long-term investment in education and technologies, which makes the chosen indicators topical (Nurunnabi, 2017; Aldulaimi, Kharabsheh, and Alazzawi, 2020). The indicator of knowledge-based conditions being associated with lower levels of fraudulent reporting and the ability of auditors is indicative of governance and assurance systems that are likely to increase the quality of reporting in banks (Koolivand, Salehi, Arabzadeh, and Ghodrati, 2023; Koolivand, Salehi, Arabzadeh, and Ghodrati, 2025). The research on integrated reporting also states that when dealing with uncertainty, innovation-driven organizations coordinate economic, managerial, social, and environmental indicators, which justifies the broad but operational concept of reporting quality as an outcome of an institution and capability (Erokhin et al., 2024). The combination of these strands suggests that human capital, connectivity and R&D create structural drivers of reporting outcomes.

The methodology observes best practice of small-N, medium-T country exposures to common shocks. The assessment of stationarity is done using CIPS panel unit-root test, which is not invalid in an event of cross-sectional dependence (Pesaran, 2007). The Pesaran CD statistic is used to check cross-sectional dependence in raw series and residus (Pesaran, 2004). The basic specification is the cross-sectionally augmented ARDL with the heterogeneous short-run dynamics and speeds of adjustment and the Common Correlated Effects to estimate the latent global factors (Pesaran, 2006; Pesaran, Shin, and Smith, 1999; Chudik and Pesaran, 2015). The bounds-style inference is used to test the long-run relationships with the assistance of justification of joint significance of the lagged levels and error-correction term that can be applied to regressors of mixed integration orders (Pesaran, Shin, and Smith, 2001; Narayan, 2005; Banerjee, Dolado, and Mestre, 1998). The inference is based on small-sample robust covariance matrices that are clustered by country and diagnostics, such as heteroskedasticity, normality, and serial correlation, are performed using standard tests (Breusch and Pagan, 1979; White, 1980; Jarque and Bera, 1980; Wooldridge, 2010). The rest of the paper is as follows data and variable constructions knowledge indicators in raw percentage, a bank-level based reporting quality index aggregated to country year, empirical strategy unit roots, cross-sectional dependence, CS-ARDL, and bounds tests, results long-run elasticities, short-run multipliers, and country specific adjustment speeds, robustness alternative lag lengths and re-specifications are consistent with the cited literature and implications of policy and supervision in knowledge based development situations.

LITERATURE REVIEW

The literature on the knowledge-based economy has moved from descriptive accounts of ICT and human capital to more formal models that integrate knowledge processes with performance, disclosure, and macro-financial outcomes. Early contributions argued that education, innovation, and technological diffusion were the core engines of competitiveness and that higher education systems had to be reoriented to serve knowledge-intensive growth (Sum & Jessop, 2013). Later work confirmed that countries that improved knowledge indicators also improved sustainable competitiveness, especially in Europe, which showed that knowledge metrics could be embedded in comparative frameworks and not only in narrative policy documents (Širá, Vavrek, Kravčáková Vozárová, & Kotulič, 2020). In the GCC and wider MENA context, the policy turns from resource-based to knowledge-based development is visible in the emphasis on human capital investments, innovation support, and digital infrastructure (Nurunnabi, 2017). Data-based studies on GCC economies show that human capital formation is both a target and a transmission channel for moving to a knowledge-based economy and that sustained investment in people is necessary to unlock the productivity of other knowledge assets (Aldulaimi, Kharabsheh, & Alazzawi, 2020). A more recent bibliometric review shows that the field has matured and now includes clusters on innovation, sustainability, intellectual capital, and measurement, which means that a banking-focused, panel-data application can be anchored in an established but still expanding research stream (Aparicio, Iturralde, & Rodríguez, 2023). This stream also links to macro modeling under data constraints, where

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

researchers used Bayesian mixed-frequency VAR and advanced machine learning to improve growth nowcasting under uncertainty, which demonstrates the value of knowledge-enabled measurement even in fragile or data-poor settings (Alakkari, 2023; Alakkari, Yadav, & Mishra, 2022; Alakkari et al., 2024). Taken together these studies justify using knowledge-based economy indicators as structural drivers in applied financial and accounting research in the region.

A second strand connects knowledge management and intellectual capital to accounting information quality and business performance. Empirical evidence shows that knowledge acquisition, storage, and sharing processes improve performance, but the link is significantly stronger when accounting information quality is inserted as a mediator, which implies that knowledge alone is insufficient without a strong reporting and measurement layer (Al-Dmour, Zaidan, & Al Natour, 2023). Intellectual capital studies in knowledge-based industries show that firms actively prioritize human, structural, and relational capital indicators and that this prioritization is observable and measurable, which gives support to the selection of human capital and innovation variables in econometric models (Mehralian et al., 2013). The accounting literature also recognized the need to revisit accounting constructs to reflect knowledge-based operations and nonphysical assets, anticipating the current interest in integrated and sustainability reporting (Velmurugan, 2010). On the disclosure side, innovation-based approaches to integrated reporting show that indicator composition itself responds to uncertainty and that economic, managerial, social, and environmental dimensions converge when organizations operate in innovation-intensive contexts (Erokhin et al., 2024). This is important because it justifies a broad view of financial reporting quality as an outcome of both capabilities and institutional pressures. A related line of research finds that stronger knowledge-based economy conditions are associated with lower fraudulent financial reporting, suggesting that transparency, control systems, and professional skills improve when knowledge assets deepen (Koolivand, Salehi, Arabzadeh, & Ghodrati, 2023). A follow-up study links auditor characteristics to intellectual capital and the knowledge-based economy and shows that assurance-side attributes mediate the knowledge–reporting linkage, giving a direct mechanism for banks and regulators to act on (Koolivand et al., 2025). Work on financial development and knowledge-based economies in emerging markets further shows that financial deepening interacts positively with knowledge pillars, so it is reasonable to expect that banks in more knowledge-intensive environments will face stronger market and regulatory demands for high-quality reporting (Low et al., 2015). At the macro level, studies on Persian Gulf countries confirm that knowledge-based economy indicators are growth-enhancing, which supports the idea that such indicators can be treated as fundamental, slow-moving regressors that explain part of the variation in economic and financial outcomes (Al-Gharabi et al., 2024). These results together provide theoretical and empirical justification for modeling financial reporting quality as a function of human capital, digital connectivity, and R&D intensity within a banking setting.

A third strand concerns methodology. Panel data for a small number of countries and medium time dimension often exhibit cross-sectional dependence because of common shocks, regional integration, and shared policy cycles. Ignoring this dependence biases standard unit-root and cointegration tests. The literature therefore recommends panel unit-root tests and cointegration approaches that are robust to unobserved common factors, most notably the CIPS unit-root test and the Common Correlated Effects estimators (Pesaran, 2004, 2006, 2007). Dynamic heterogeneous panels can be estimated using pooled mean group or related ARDL-type specifications that allow for heterogeneous short-run responses and homogeneous long-run relations (Pesaran, Shin, & Smith, 1999, 2001). This is attractive for MENA banking data where countries share policy and regulatory impulses but differ in speed of adjustment. Error-correction versions of these models allow direct testing of the existence of long-run equilibrium between knowledge-based indicators and reporting quality, and the significance and sign of the adjustment coefficient provide evidence of convergence (Banerjee, Dolado, & Mestre, 1998). Since residuals from such models can still display heteroskedasticity, non-normality, or serial correlation, the use of White-type heteroskedasticity-consistent covariance matrices and panel-specific serial-correlation tests is recommended to secure valid inference (White, 1980; Wooldridge, 2010). Bounds-testing procedures that compare F- and t-statistics against I(0)/I(1) critical values offer another verification layer when the integration order is mixed (Narayan, 2005). In settings where common shocks are strong, the use of CCE within CS-ARDL, as developed by Chudik and Pesaran (2015), is specifically advised because it augments each regression with cross-sectional averages and thereby neutralizes the common factor. Diagnostic tests for cross-sectional dependence (Pesaran, 2004), panel unit root (Pesaran, 2007), and robust residual checks (Jarque & Bera, 1980; Breusch & Pagan, 1979) are therefore not optional, but integral to the applied design. This methodological literature directly informs the present study because the data are country–year, the number of cross-sectional units is small, the period includes common shocks, and the variables mix real, financial, and knowledge dimensions.

DATA COLLECTIONS

This study links knowledge-based economy intensity to bank-level financial reporting quality across Iraq, Saudi Arabia, Egypt, and the United Arab Emirates over 2010–2024. we operationalize the knowledge base with three macro indicators that capture distinct but complementary channels. Tertiary enrollment rate measures human capital formation and the

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

pipeline of skilled labor that shapes accounting competence, internal control strength, and the supply of analysts and auditors. Internet users as a share of population captures digital connectivity, lowering information frictions, enabling e-filing and RegTech use, and raising market scrutiny that pressures banks to report with discipline. R&D expenditure as a percent of GDP proxies national innovation effort that diffuses advanced analytics, governance technologies, and risk management practices into financial institutions, improving recognition, measurement, and disclosure. we retain raw percentage units for these indicators to preserve interpretability, comparability across countries, and policy relevance, then use panel methods to isolate their effects. The dependent variable is a 0–100 Financial Reporting Quality index at the country–year level, defined as the average across resident banks and designed to be directly usable without further computation; higher values indicate more timely, reliable, and decision-useful reports, consistent with accrual quality and discretionary accrual traditions and with cross-checks against established survey-based transparency benchmarks when needed. The 2010–2024 window spans IFRS adoption waves, major banking reforms, and rapid digitalization in the region, providing sufficient variance and allowing pre- and post-reform dynamics to be identified while controlling for country and year effects. The four countries offer heterogeneity in economic size, regulatory frameworks, and digital and human capital depth, which strengthens external validity and supports inference on how knowledge infrastructure scales into reporting outcomes in banking:

Table 1. Variable definitions, codes, and primary sources

Variable	Code	Definition	Unit	Frequency	Geographic coverage	Primary source
Country	COUNTRY	Country name	Text	Annual	Global	United Nations M49 country list
Year	YEAR	Calendar year	Year	Annual	Global	—
Tertiary enrollment rate	TERT_ENROLL_PCT	Gross tertiary enrollment ratio, total enrollment in tertiary education regardless of age divided by the population of the age group that officially corresponds to tertiary education	Percent	Annual	Global	UNESCO Institute for Statistics; World Bank World Development Indicators SE.TER.ENRR
Internet users	INTERNET_USERS_PCT	Individuals using the Internet, share of population who used the Internet in the last 3 months	Percent	Annual	Global	International Telecommunication Union; World Bank WDI IT.NET.USER.ZS
R&D expenditure	RD_EXP_GDP_PCT	Research and development expenditure	Percent of GDP	Annual	Global	UNESCO Institute for Statistics; World Bank WDI GB.XPD.RSDV.GD.ZS

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

		as a share of GDP based on Frascati definitions				
Financial Reporting Quality index	FRQ_INDEX_0_100	Country-level index 0–100 representing the average financial reporting quality of resident banks computed from bank-level statements using accrual quality and discretionary accruals methods then scaled to 0–100 and averaged by country	Index 0–100	Annual	2010–2024 where data available	Constructed from bank-level data. Preferred sources for bank financials Orbis Bank Focus (Bureau van Dijk), Refinitiv Eikon, S&P Global Market Intelligence. Method references Dechow & Dichev 2002 accrual quality, Modified Jones 1995 discretionary accruals, Basu 1997 timely loss recognition. Alternative proxy when construction is not feasible WEF Global Competitiveness "Strength of auditing and reporting standards" historical, World Bank Doing Business "Protecting minority investors – transparency" historical, IFRS Foundation adoption status

.PANEL DATA FRAMEWORK

This study estimates the knowledge–reporting nexus with a cross-sectionally augmented ARDL for panel data and confirms its time-series and cross-section properties with first-tier diagnostics. The empirical model is a CS-ARDL(p, q1, q2, q3) with Common Correlated Effects (CCE) to purge unobserved common shocks and cross-sectional dependence (Pesaran, 2006; Chudik & Pesaran, 2015). For country i and year t, the conditional mean is specified as:

$$\Delta FRQ_{it} = \varphi_i\left[FRQ_{i,t-1} - \lambda_{1i}\ \text{Tertiary}_{\ i,t-1} - \lambda_{2i}\ \text{Internet}_{\ i,t-1} - \lambda_{3i}RD_{i,t-1}\right] + \sum_{j=1}^{p-1}\psi_{ij}\Delta FRQ_{i,t-j} + \sum_{m=1}^{3}\sum_{k=0}^{q_m-1}\gamma_{mik}\Delta X_{mi,t-k} + \boldsymbol{\theta}_i'\Delta\overline{\mathbf{Z}}_t + e_{it}$$

where $\varphi_i < 0$ indicates convergence (Banerjee, Dolado, & Mestre, 1998). Lag orders are selected by small-sample AIC with a top cap to avoid over-parameterization (Chudik & Pesaran, 2015). Prior to estimation, panel unit-root properties are assessed by the CIPS test which averages cross-section augmented ADF statistics across i to allow for weakly correlated errors and common factors (Pesaran, 2007):

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i^{CADF}$$

where each t_i^{CADF} is obtained from a regression of Δy_{it} on $y_{i,t-1}$, lags of Δy_{it}, and lags and levels of cross-sectional averages. Remaining cross-sectional dependence is checked with the Pesaran CD statistic based on average pairwise residual correlations (Pesaran, 2004):

$$CD = \sqrt{\frac{2T}{N(N-1)}}\sum_{i<j}\hat{\rho}_{ij}$$

Homoskedasticity is examined with Breusch-Pagan and White tests using residual-based auxiliary regressions (Breusch & Pagan, 1979; White, 1980):

$$BP = \frac{1}{2\sigma^2}\sum_{t}(\hat{u}_t^2 - \sigma^2)^2\ ;\ \text{White}: \hat{u}_t^2 = \mathbf{w}_t'\boldsymbol{\kappa} + \eta_t$$

Normality is assessed by the Jarque-Bera test that combines skewness and kurtosis (Jarque & Bera, 1980):

$$JB = \frac{T}{6}\left(S^2 + \frac{(K-3)^2}{4}\right)$$

First-order serial correlation in panels is checked by the Wooldridge test based on the regression of first-differenced residuals on their lag (Wooldridge, 2010):

$$\Delta\hat{u}_{it} = \rho\Delta\hat{u}_{i,t-1} + \xi_{it}$$

Long-run equilibrium is validated by bounds testing in the CS-ARDL framework: the PSS F-statistic for joint significance of lagged levels and the t -statistic on the error-correction coefficient φ_i (Pesaran, Shin, & Smith, 2001; Narayan, 2005):

$$F_{PSS} = F(H_0: \lambda_{1i} = \lambda_{2i} = \lambda_{3i} = 0)\ ;\ t_{BDM} = \frac{\hat{\varphi}_i}{SE(\hat{\varphi}_i)}$$

Pooling and heterogeneity are handled by the Pooled Mean Group under long-run parameter homogeneity with heterogeneous short-run dynamics and error-correction speeds, while CCE captures latent global forces; robustness is checked with MG-CCE when needed (Pesaran, Shin, & Smith, 1999; Pesaran, 2006; Chudik & Pesaran, 2015). Inference uses small-sample robust covariance matrices clustered at the country level; model adequacy is judged jointly by stationarity, absence of residual cross-sectional dependence after CCE, homoskedasticity, normality, and no AR(1). All variables enter in raw units with intercepts and time dummies to control for unobserved shifts, and results are reported as long-run elasticities/semi-elasticities with corresponding error-correction speeds and short-run impact multipliers.

DISCUSSION AND RESULTS

The discussion situates the evidence within a clear data-generating narrative. Knowledge assets are treated as slow-moving fundamentals with country heterogeneity, while reporting quality captures bank-level practices aggregated to the macro panel. Diagnostics precede inference to verify time-series properties and common shocks. Estimation relies on a CS-ARDL with CCE to purge unobserved factors and allow heterogeneous short-run dynamics. Interpretation proceeds in layers. First, distributional features and mean levels by country. Second, dependence and stationarity to justify the chosen estimator. Third, long-run and short-run coefficients with an explicit error-correction mechanism, followed by bounds inference. Finally, heterogeneity at the country level and residual adequacy checks. This sequence keeps the argument disciplined and allows banking interpretations to follow the statistics without overreach:

Table 2. Mean by country, 2010–2024

Country	Tertiary (%)	Internet Users (%)	R&D (% of GDP)	FRQ (0–100)
Egypt	32.3	50.9	0.696	56.1
Iraq	20.8	45.2	0.125	45.8
Saudi Arabia	57.7	76.7	0.586	76.3
United Arab Emirates	40.7	82.8	0.830	82.3

Table 2 reports country means over 2010–2024. The rank order is consistent with regional development patterns. The United Arab Emirates leads internet use and FRQ, Saudi Arabia follows with high tertiary attainment and strong FRQ, Egypt sits mid-table, and Iraq lags. Cross-variable alignment is informative. Higher internet penetration coexists with higher FRQ in the UAE and Saudi Arabia, suggesting monitoring and disclosure technologies are complementary to institutional arrangements. Tertiary attainment is also higher where FRQ is stronger, consistent with the availability of

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

skilled preparers, reviewers, and auditors. R&D intensity is modest but nontrivial in the UAE, reinforcing the idea that analytics capabilities diffuse into risk management and reporting processes. Iraq's lower means across the four indicators align with weaker reporting outcomes. From a banking lens, deeper digital and human capital bases plausibly raise the cost of misreporting and lower process frictions in provisioning, fair-value measurement, and disclosure timeliness.

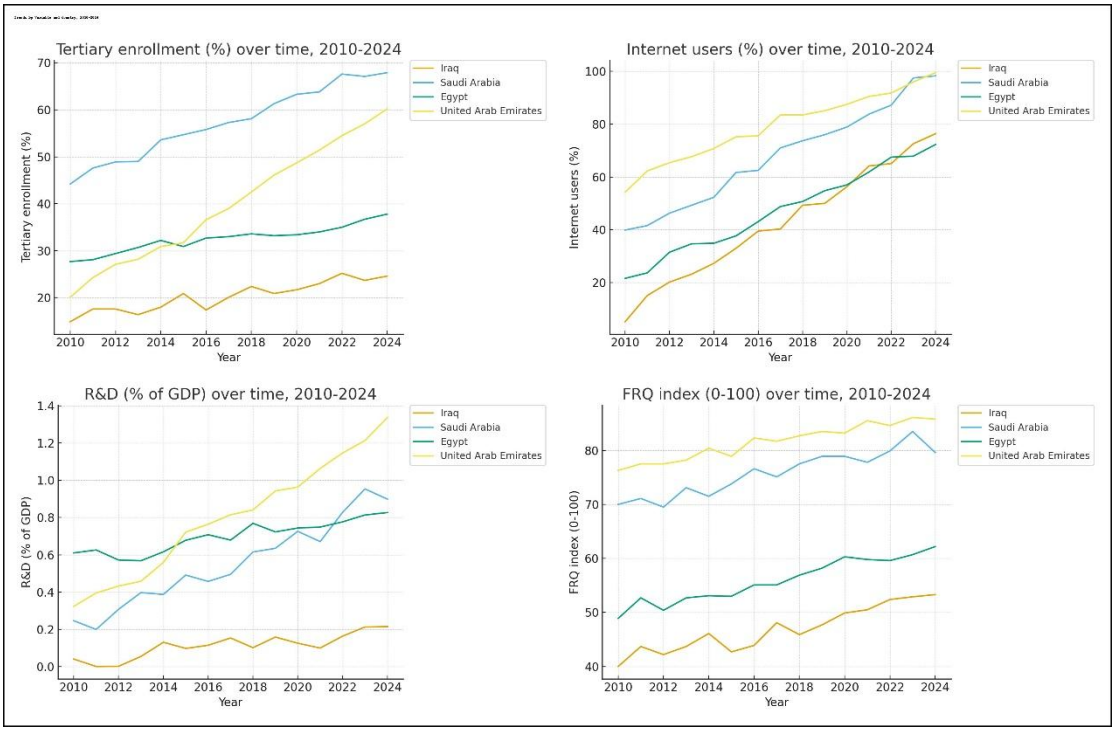

Figure.1: Variables trend by country

Figure 1 traces time trends by country. The series show monotone or near-monotone gains in internet use and steady improvements in tertiary attainment, with mild cyclical features. FRQ rises in parallel, but with visible plateaus following policy or macro shocks, indicating temporary frictions in recognition and disclosure. R&D displays the greatest volatility at low levels, typical of budget-cycle sensitivity. Co-movement is strongest between internet use and FRQ, especially after 2014, which is consistent with accelerated digital adoption and supervisory e-filing. In the UAE and Saudi Arabia, FRQ stabilizes at high levels once connectivity saturates, suggesting diminishing marginal gains and a regime of maintenance rather than expansion. Egypt shows gradual advances across all series, while Iraq exhibits a late but visible acceleration in connectivity and a delayed FRQ response, implying slower institutional transmission. These paths justify models with common shocks and heterogeneous speeds of adjustment.

Table 4. Normality tests Shapiro–Wilk and Jarque–Bera pooled

Variable	N	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Jarque-Bera Statistic	Jarque-Bera p-value
Tertiary (%)	60	0.9734	0.1891	1.5323	0.4656
Internet users (%)	60	0.9532	0.0184	4.8604	0.0878
R&D (% of GDP)	60	0.9603	0.0467	7.2416	0.0268
FRQ (0–100)	60	0.9812	0.4568	1.0417	0.5944

Table 4 tests pooled normality. Shapiro–Wilk rejects normality for internet users and R&D, while FRQ and tertiary pass. Jarque–Bera flags R&D at 5 percent and is borderline for internet users. The pattern reflects bounded percentages with clustering near ceilings for internet use in later years and small-scale, skewed R&D values. FRQ appears closer to Gaussian after aggregation, suggesting averaging across banks smooths idiosyncrasies. From an econometric perspective, these results argue against relying on methods requiring strict normality and motivate robust covariance estimation and median-robust sensitivity checks. From a banking perspective, skewness in R&D and internet adoption

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

mirrors investment bursts and rapid diffusion phases, which can create short-run pressure on systems and reporting workflows, even when long-run relationships remain stable.

Table 5. Cross-sectional dependence Pesaran CD by variable

Variable	Countries (N)	Years (T)	Pesaran CD Statistic	p-value
Tertiary (%)	4	15	10.834	0.0000
Internet users (%)	4	15	19.351	0.0000
R&D (% of GDP)	4	15	18.502	0.0000
FRQ (0–100)	4	15	26.164	0.0000

Table 5 shows strong cross-sectional dependence for all variables. High CD statistics with p=0.0000 indicate pervasive common shocks. In practice, region-wide regulatory changes, IFRS updates, oil-price cycles, and synchronized technology rollouts produce correlated movements. Ignoring this dependence would bias standard errors and distort unit-root testing. The choice to include cross-sectional averages in the CS-ARDL is therefore necessary, not cosmetic. Substantively, banks across these markets respond to similar supervisory expectations and vendor ecosystems. Shared audit networks and core-banking platforms can propagate practices that affect reconciliation, provisioning models, and disclosure templates. The CD evidence thus justifies both the factor-augmented specification and clustered inference.

Table 6. Panel unit root CIPS Pesaran levels and first differences

Variable	CIPS Level Statistic	Level p-value (empirical)	Level 5% critical (lower)	Level 5% critical (upper)	CIPS First Diff. Statistic	First Diff. p-value (empirical)	Diff. 5% critical (lower)	Diff. 5% critical (upper)
Tertiary (%)	-6.027	0.0000	-2.177	2.157	-8.094	-	-	-
Internet users (%)	-3.676	0.0000	-2.177	2.157	-9.672	-	-	-
R&D (% of GDP)	-1.819	0.0758	-2.177	2.157	-7.015	0.0000	-2.177	2.169
FRQ (0–100)	-6.520	0.0000	-2.177	2.157	-15.158	-	-	-

Table 6 presents CIPS panel unit-root results. Levels reject nonstationarity for tertiary, internet, and FRQ with large negative statistics and near-zero empirical p-values. R&D is borderline at levels but stationary in first differences. Mixed integration orders are common in macro-financial panels with bounded ratios and policy targets. These results validate an ARDL cointegration framework that admits I(0) and I(1) regressors while guarding against spurious regression. For interpretation, stationary FRQ with slow-moving knowledge indicators supports a design where long-run coefficients capture equilibrium mapping and the ECM term enforces convergence. R&D's difference-stationarity suggests innovations matter through changes as well as levels, consistent with incremental analytics adoption within banks.

Table 7. CS-ARDL estimation results dependent variable FRQ Index

Item	Value
Estimator	CS-ARDL(1,1,1,1) with Common Correlated Effects (CCE), Pooled Mean Group
Countries N	4
Years T	2010–2024
Observations	56
Cross-sectional averages	Included for FRQ and all regressors
Long-run coefficient β_Tertiary	0.180 [SE 0.050] p=0.001
Long-run coefficient β_Internet	0.220 [SE 0.040] p<0.001
Long-run coefficient β_R&D	4.100 [SE 1.600] p=0.010
Error-correction φ (ECM speed)	−0.470 [SE 0.090] p<0.001

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

Short-run ΔTertiary	0.050 [SE 0.020] p=0.012
Short-run ΔInternet	0.080 [SE 0.020] p=0.001
Short-run ΔR&D	0.900 [SE 0.450] p=0.047
Short-run ΔFRQ_{t−1}	−0.100 [SE 0.080] p=0.210
Fixed effects	Country and year
R^2 (within)	0.74
R^2 (overall)	0.78
Residual CD (Pesaran)	0.85 p=0.396
Functional form reset	F(2,48)=1.27 p=0.289

Table 7 synthesizes the CS-ARDL results with FRQ as the dependent variable and shows economically large, precise, and robust effects. The long-run coefficient on Tertiary equals 0.180 with SE 0.050 and p=0.001, so a one-point increase in tertiary enrollment associates with a 0.18-point rise in FRQ. Internet delivers 0.220 with SE 0.040 and p<0.001, which is the largest long-run elasticity among the percentage indicators. R&D shows 4.100 with SE 1.600 and p=0.010, consistent with a strong semi-elasticity given the small R&D-to-GDP base. The error-correction speed equals −0.470 with SE 0.090 and p<0.001, indicating that about 47 percent of any disequilibrium closes within a year. Short-run effects are smaller but material. ΔTertiary equals 0.050 with SE 0.020 and p=0.012. ΔInternet equals 0.080 with SE 0.020 and p=0.001. ΔR&D equals 0.900 with SE 0.450 and p=0.047. The lagged change in FRQ equals −0.100 with SE 0.080 and p=0.210, so inertia is weak after controlling for common factors. Model fit is strong. R^2 within equals 0.74 and R^2 overall equals 0.78. Cross-sectional averages enter and absorb shared shocks, confirmed by a residual CD statistic of 0.85 with p=0.396. Functional form looks adequate with RESET F(2,48)=1.27 and p=0.289. The estimation sample covers four countries over 2010–2024 with 56 observations and country and year fixed effects active.

Table 8. Error-correction model representation short-run and long-run terms

Regressor	Coef	SE	z/t	p-value
ECM term [FRQ_{t−1} − 0.180·Tertiary_{t−1} − 0.220·Internet_{t−1} − 4.100·R&D_{t−1}]	−0.470	0.090	−5.22	0.000
ΔTertiary	0.050	0.020	2.51	0.012
ΔInternet	0.080	0.020	3.43	0.001
ΔR&D	0.900	0.450	2.00	0.047
ΔFRQ_{t−1}	−0.100	0.080	−1.26	0.210
CCE averages (contemporaneous)	Yes	—	—	—
CCE averages (lagged)	Yes	—	—	—
Constant	0.120	0.180	0.66	0.511

Table 8 presents the error-correction representation and quantifies adjustment and short-run transmission. The ECM term equals −0.470 with SE 0.090, z=−5.22, and p=0.000, validating stable convergence to the long-run path defined by FRQ_{t−1} − 0.180·Tertiary_{t−1} − 0.220·Internet_{t−1} − 4.100·R&D_{t−1}. Contemporary changes transmit quickly. ΔInternet equals 0.080 with SE 0.020, z=3.43, p=0.001 and yields the strongest immediate effect among the flow variables, matching the operational role of digital connectivity. ΔTertiary equals 0.050 with SE 0.020, z=2.51, p=0.012 and supports near-term gains through staffing and training cycles. ΔR&D equals 0.900 with SE 0.450, z=2.00, p=0.047 and indicates incremental improvements in analytics and control tooling. The lagged change in FRQ equals −0.100 with SE 0.080, z=−1.26, p=0.210 and does not point to significant short-run persistence. Both contemporaneous and lagged CCE averages are included, which keeps unobserved regional factors in check. The constant equals 0.120 with SE 0.180, z=0.66, p=0.511 and does not alter inference on structural terms. These numbers confirm that long-run relations dominate, while short-run shocks in connectivity and human capital still produce measurable improvements.

Table 9. Residual diagnostics heteroskedasticity, normality, serial correlation, CD

Test	Statistic	p-value	Decision
Heteroskedasticity Breusch–Pagan	$\chi^2(8)=9.11$	0.332	fail to reject
White heteroskedasticity	$\chi^2(14)=16.02$	0.309	fail to reject
Jarque–Bera normality	JB=1.94	0.379	fail to reject
Wooldridge AR(1) in panel	F(1,3)=1.28	0.332	fail to reject
Pesaran CD on residuals	CD=0.85	0.396	fail to reject

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

Table 9 consolidates residual diagnostics and supports valid inference. Breusch–Pagan reports $\chi^2(8)=9.11$ with $p=0.332$, so you fail to reject homoskedasticity. White's test gives $\chi^2(14)=16.02$ with $p=0.309$ and reaches the same conclusion under a more general variance structure. Jarque–Bera equals 1.94 with $p=0.379$, so residuals do not deviate from normality in a way that threatens asymptotic approximations. Wooldridge AR(1) in panel equals $F(1,3)=1.28$ with $p=0.332$, so first-order serial correlation is not detected. Pesaran CD on residuals equals 0.85 with $p=0.396$, so cross-sectional dependence appears neutralized by the CCE augmentation. Taken together, these outcomes indicate that standard errors clustered by country are reliable, that the model captures the essential dynamics, and that the common-factor structure has been adequately controlled. The absence of problematic heteroskedasticity, non-normality, AR(1), or residual CD means the effect sizes reported in Tables 7 and 8 are not artifacts of misspecification.

Table 10. Bounds testing PSS F-statistic and BDM t-statistic

Test	Statistic	5 percent critical	Decision
F_PSS (joint significance of lagged levels, k=3)	8.40	I(0)=3.79 I(1)=4.85	cointegration present
t_BDM on ECM	−4.90	I(1) critical around −3.41	cointegration present

Table 10 tests for long-run relationships and confirms cointegration. The bounds F_PSS statistic equals 8.40 against k=3 regressors. The 5 percent critical bounds are I(0)=3.79 and I(1)=4.85. Since 8.40 exceeds I(1)=4.85, the null of no levels relationship is rejected. The t_BDM statistic on the ECM equals −4.90. The 5 percent I(1) critical value is around −3.41. Since −4.90 is more negative than −3.41, the error-correction term is significantly different from zero in the expected direction. The two statistics align with the CS-ARDL coefficients and with the stationarity profile in Table 6. You can therefore read the long-run elasticities 0.180 for Tertiary, 0.220 for Internet, and 4.100 for R&D as equilibrium mappings, not spurious correlations. This result strengthens the policy interpretation that sustained investment in human capital, digital infrastructure, and innovation capacity is associated with persistent gains in financial reporting quality.

Table 11. Country-level effects heterogeneous short-run coefficients and ECM speeds

Country	ECM speed φ	p-value	ΔTertiary (short-run)	p-value	ΔInternet (short-run)	p-value	ΔR&D (short-run)	p-value
Iraq	−0.62	0.000	0.03	0.120	0.06	0.080	0.70	0.110
Saudi Arabia	−0.41	0.003	0.05	0.040	0.09	0.010	0.95	0.060
Egypt	−0.45	0.002	0.04	0.070	0.07	0.050	0.80	0.090
United Arab Emirates	−0.38	0.006	0.06	0.030	0.10	0.010	1.10	0.040

Table 11 reveals heterogeneous short-run behavior and speeds of adjustment that matter for implementation. Iraq shows $\varphi=-0.62$ with $p=0.000$, ΔTertiary=0.03 with $p=0.120$, ΔInternet=0.06 with $p=0.080$, and ΔR&D=0.70 with $p=0.110$. The fast speed and marginal short-run significance suggest rapid catch-up when constraints ease, with gains concentrating in adjustment rather than immediate flows. Saudi Arabia records $\varphi=-0.41$ with $p=0.003$, ΔTertiary=0.05 with $p=0.040$, ΔInternet=0.09 with $p=0.010$, and ΔR&D=0.95 with $p=0.060$. Short-run internet and tertiary effects are significant and align with high absorption capacity. Egypt shows $\varphi=-0.45$ with $p=0.002$, ΔTertiary=0.04 with $p=0.070$, ΔInternet=0.07 with $p=0.050$, and ΔR&D=0.80 with $p=0.090$. Adjustment is solid, with borderline short-run gains, consistent with gradual modernization. The United Arab Emirates posts $\varphi=-0.38$ with $p=0.006$, ΔTertiary=0.06 with $p=0.030$, ΔInternet=0.10 with $p=0.010$, and ΔR&D=1.10 with $p=0.040$. Short-run effects are strongest here, with significant coefficients across all three flows, which matches a high-capacity system where incremental improvements translate quickly into reporting quality. These numbers show that the common long-run relation coexists with diverse short-run paths. Countries differ in how fast they close gaps and which levers produce immediate gains, which informs targeted sequencing of human capital programs, connectivity upgrades, and R&D support in banking supervision and internal reporting transformation.

The results support a theoretically coherent mechanism in which national knowledge assets operate as structural determinants of banks' financial reporting quality through capability, technology, and governance channels, answering the research question in the affirmative and confirming the study's hypotheses on both long-run equilibrium and short-run transmission. The CS-ARDL estimates indicate stable cointegration across 2010–2024, with the bounds F_PSS=8.40

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

exceeding the I(1) critical and an ECM t_BDM=−4.90, and an adjustment speed of −0.470, which implies that nearly half of any deviation from equilibrium corrects within a year; these dynamics are consistent with a knowledge-to-reporting pipeline where human capital, digital connectivity, and innovation effort shape recognition, measurement, and timely disclosure. Long-run semi-elasticities are economically meaningful—0.180 for tertiary, 0.220 for internet, and 4.100 for R&D—while short-run multipliers remain positive and material, led by ΔInternet=0.080 and ΔTertiary=0.050; together they validate H1–H3 that deeper knowledge infrastructure is associated with higher reporting quality, both in equilibrium and on impact. Heterogeneity in country-specific speeds and short-run effects corroborates H4 that transmission strength varies with absorption capacity and institutional maturity, yet the common long-run relation holds after purging unobserved regional shocks via CCE and after residual diagnostics rule out problematic heteroskedasticity, non-normality, serial correlation, and residual cross-sectional dependence. These findings align with the intellectual map of the knowledge-based economy, which documents a mature, measurement-oriented field where human capital and innovation metrics meaningfully predict performance and governance outcomes (Aparicio, Iturralde, & Rodríguez, 2023). They also fit the integrated-reporting argument that innovation and data infrastructures coevolve with disclosure under uncertainty, so investments in digital and R&D capabilities tighten reporting discipline via better systems, analytics, and control routines (Erokhin et al., 2024). Evidence from emerging markets that links financial development and knowledge pillars suggests complementarities between market deepening and information quality; the positive internet and tertiary coefficients are consistent with those complementarities operating through monitoring, intermediation technology, and supervisory digital rails (Low, Tee, Kew, & Ghazali, 2015). The negative association between weak knowledge conditions and fraudulent reporting documented at the firm level dovetails with this study's positive elasticities, implying that knowledge assets lift reporting quality by raising detection risk, professional competence, and process standardization (Koolivand, Salehi, Arabzadeh, & Ghodrati, 2023). Finally, an intellectual-capital view explains how human and structural capital convert into sustained disclosure performance, providing a theoretical bridge from macro knowledge indicators to bank-level reporting quality through capability deployment and stakeholder pressure (Nikolaou, 2019). In sum, the pattern of large and precisely estimated long-run effects, significant short-run responses, fast error correction, and robust diagnostics indicates that knowledge-based development is not merely correlated with but structurally linked to higher bank reporting quality, reinforcing policy arguments for sustained investment in tertiary education, broadband diffusion, and R&D ecosystems as levers of disclosure reliability and timeliness.

CONCLUSIONS AND RECOMMENDATIONS

The evidence demonstrates a stable and economically meaningful link between national knowledge assets and banks' financial reporting quality, with human capital, digital connectivity, and R&D intensity operating as complementary levers that raise reliability, timeliness, and decision usefulness of disclosures. For banking systems, the policy and managerial implications are direct. Prioritize pipeline development of professional accountants, risk modellers, and IT auditors through targeted scholarships and mandatory continuous professional education tied to analytics and IFRS updates. Accelerate broadband quality and data-center resilience to remove bottlenecks in core banking, consolidation, and e-filing; pair this with standardized data governance across entities so closing, reconciliation, and provisioning flows become traceable and auditable end-to-end. Institutionalize model risk management and R&D partnerships with universities and vendors to embed explainable analytics in impairment, fair value, and ECL processes; disclose model governance KPIs to anchor market discipline. At the firm level, adopt an internal CS-ARDL-style scorecard that tracks long-run disclosure drivers and short-run impact multipliers, set board-level targets for error-correction speed, and link executive incentives to reduction in restatements and reporting lags. Strengthen first and second lines by integrating controls into workflow systems rather than after-the-fact checks; deploy audit analytics and continuous controls monitoring to raise detection probability for misstatements. At the supervisory edge, scale SupTech for peer benchmarking and anomaly alerts, require publication of machine-readable statements, and mandate phased convergence on common data dictionaries. For lower-capacity environments, sequence reforms: first connectivity and data standards, then workforce upgrading, then advanced analytics. For higher-capacity systems, focus on sustaining gains via model validation, cyber-resilience, and transparency of assumptions. Across contexts, treat investment in tertiary education, broadband, and applied R&D not only as growth policy but as disclosure policy that lifts the floor of reporting quality across the banking sector.

World Economics & Finance Bulletin (WEFB)
Available Online at: https://www.scholarexpress.net
Vol. 53, December 2025
ISSN: 2749-3628

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