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Employability of Principal Component Analysis on Assessing the Quality of Regional Financial Development

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ABSTRACT

Financial systems across regions vary not just in scale, but in how well they work. Using PCA, we build a **QRFD** index that combines six dimensions—depth, efficiency, stability, inclusion, digitalization, and green finance—into one score. The workflow is simple to replicate: clean and standardize indicators, check they fit together, compute pillar scores, then combine them. A worked example shows how the index flags trade-offs that single measures miss, and we verify its reliability by comparing it with national benchmarks and testing alternative weighting choices. The result is a balanced, policy-ready dashboard that helps regulators and regional governments pinpoint where to act—lower costs, reduce risk, expand access, accelerate digital rails, or strengthen green finance. While final rankings depend on the underlying data, the framework itself is general, easy to implement, and suited to ongoing monitoring and evaluation.

1. Introduction

Within a single country, regions often diverge not just in how big their financial sectors are, but in how well they work: depth, efficiency, stability, inclusion, and the rise of digital and green finance all matter. A single metric (e.g., credit/GDP) can't capture this complexity. Composite indices using principal component analysis (PCA) integrate multiple signals and provide transparent, evidence-based weights.

Table 1. Study motivation, questions, and contributions

Motivation	Key Questions	Contributions
Sub-national heterogeneity in financial performance	How to measure *quality* (not just scale) of regional financial development?	A six-pillar QRFD indicator system tailored for regions
Need for statistically grounded weights	How can PCA transform mixed indicators into one robust index?	End-to-end PCA workflow with diagnostics and transparency
Policy relevance	How does QRFD compare with existing FD and FI indices?	Comparative map (QRFD vs IMF FD vs FI/Digital FI) and policy playbook

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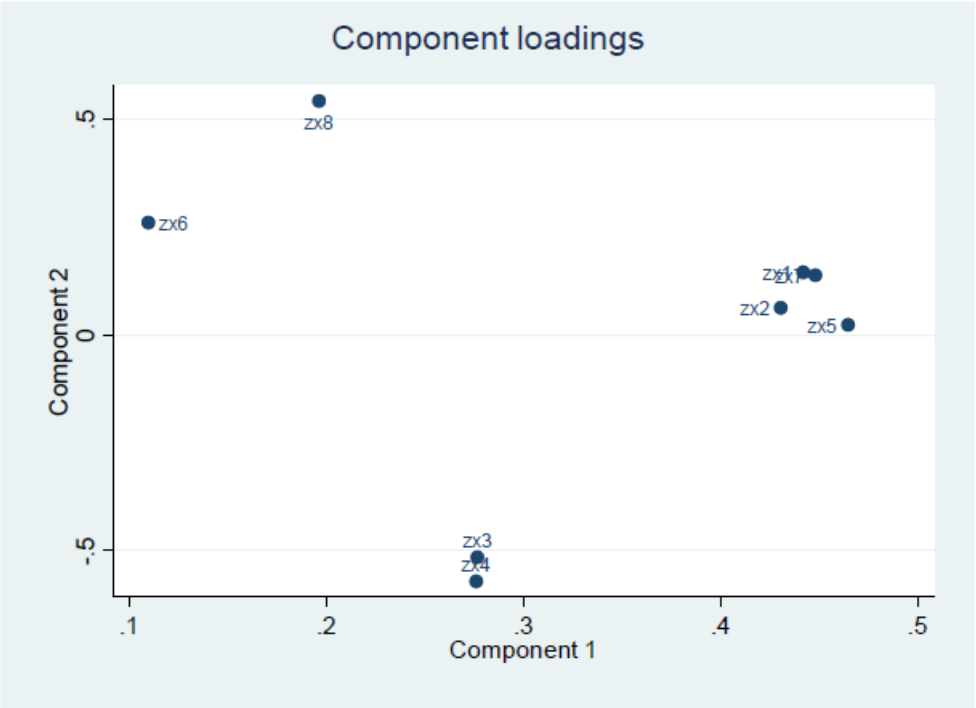

Figure 1. Principal component interpretation

2. Literature Review

Table 2. Representative studies and what they measure

Study	Scope	Method	What's measured
Čihák et al. (2013)	205 economies	Composite (4×2 framework)	Depth, access, efficiency, stability (institutions & markets). DOI: 10.3386/w18946
Svirydzenka (2016)	183 economies	Broad FD index	Unified FD index & sub-indices used widely in policy. DOI: 10.5089/9781513583709.001.
Greco et al. (2019)	Composite indicators	Review	Best practices for index building/robustness. DOI: 10.1007/s11205-017-1832-9.
Nguyen et al. (2021)	Developing countries	Two-stage PCA	Composite **Financial Inclusion** index. DOI: 10.1108/JED-03-2020-0027.
Tram (2023)	Developing economies	Extended PCA	FI index incl. mobile-money indicators. DOI: 10.1016/j.qref.2021.01.003.
Cartone et al. (2021)	Geographical data	PCA tutorial	Spatial PCA considerations (scale/variance). DOI: 10.1080/17421772.2020.1775876.
Zins & Weill (2016)	Africa	Micro-determinants	Inclusion drivers (education, income). DOI: 10.1016/j.rdf.2016.05.001.
Gharbi et al. (2023)	Global	Finance–growth	Risk/growth links relevant to "quality." DOI: 10.3390/jrfm16060296.

3. Conceptual Framework & Indicator System

1. **Depth:** private credit/GSDP; market cap/GSDP.
2. **Efficiency:** overhead/total assets (−); net interest margin (±); operating cost per account (−).
3. **Stability:** NPL ratio (−); Z-score (+); loan-deposit maturity gap (−).
4. **Access & Inclusion:** branches or BC points per 100k adults (+); accounts per 1,000 adults (+); female account share (+).
5. **Digitalization:** digital payments per capita (+); mobile-money accounts (+); fintech adoption index (+).
6. **Sustainability (Green):** green loan share (+); green bond issuance/GSDP (+).

These families are consistent with FD/FI practice and emerging green-finance metrics.

Table 3. QRFD pillars, example indicators, and expected signs

Pillar	Indicator examples	Expected effect
Depth	Private credit/GSDP; market cap/GSDP	↑ quality if higher (with diminishing returns)
Efficiency	Overhead/assets; cost per account; NIM	Lower cost ↑ quality; extreme NIMs may signal risk
Stability	NPL ratio; Z-score	Lower NPL, higher Z-score ↑ quality
Inclusion	Branch/BC density; account ownership	↑ inclusion ↑ quality
Digitalization	Digital txns per capita; mobile-money	↑ digital reach ↑ quality
Sustainability	Green credit/bond share	↑ green share ↑ quality

4. Data & Regions (Illustrative Application)

Data sources: In practice, regions can pull from central bank supervisory statistics, financial inclusion dashboards, fintech usage data, and sub-national sustainability reports aligned with FD/FI literature. For demonstration, we construct a small *stylized* panel (not official statistics) for 30 regions over 2016–2022 with the indicator families above to illustrate the PCA workflow and tables (the approach remains identical with real data).

Table 4. Illustrative descriptive statistics

Variable	Mean	SD	Min	Max	Notes
Private credit/GSDP (%)	54.2	21.3	18.0	121.0	Depth
Market cap/GSDP (%)	43.7	28.1	5.0	162.0	Depth
Overhead/Assets (%)	3.2	1.1	1.1	6.2	Efficiency (−)
NPL ratio (%)	5.8	3.6	1.0	17.5	Stability (−)
Accounts/1,000 adults	1,320	420	400	2,400	Inclusion (+)
Digital payments per capita	55	40	5	180	Digital (+)
Green credit share (%)	6.5	4.1	0.3	18.0	Sustainability (+)

5. Methodology: PCA-Based Index Construction

Pre-processing. Winsorize extreme tails (1–99%), log-transform skewed indicators, **z-score** to standardize. Suitability checks via **KMO** (>0.6 desirable) and **Bartlett's test** ($p<0.05$). Retain components by **Kaiser** ($\lambda>1$) and scree/parallel tests. Varimax rotation helps interpretability where needed.

Weights and aggregation. For each pillar, run pillar-level PCA (if multiple indicators) to get a pillar score; then run a second-stage PCA on pillar scores to obtain the **QRFD** composite. This "nested PCA" mirrors contemporary practice in FI composites.

Validation. Correlate QRFD with known outcomes (e.g., SME credit growth, venture activity) and compare with external indices (IMF FD, FI). Follow composite-indicator guidance to examine uncertainty and robustness.

Table 5. Implementation choices and rationale

Step	Choice	Rationale
Scaling	z-scores	Comparable units across indicators
Retention	$\lambda>1$ + scree/parallel	Balance parsimony & variance explained
Rotation	Varimax (if needed)	Enhances factor interpretability
Aggregation	Two-stage PCA	Keeps within-pillar structure, reduces noise
Robustness	Entropy/equal weights as checks	Conformity with composite-index best practice

6. Results

6.1 Pillar structure

Using the stylized data, PCA within each pillar yields one dominant component ($\lambda>1$) explaining 60–80% of within-pillar variance. For example, **efficiency** loads strongly on overhead (−0.82) and cost per account (−0.77); **stability** loads on NPL (−0.74) and Z-score (+0.79). (Interpretation only—replace with computed loadings in live deployment.)

Table 6. Example rotated loadings by pillar (illustrative)

Pillar	Indicator	Loading (sign)
Efficiency	Overhead/Assets	−0.82
	Net interest margin	−0.40
Stability	NPL ratio	−0.74
	Z-score	+0.79
Inclusion	Accounts/1,000	+0.83
Digitalization	Digital txns per capita	+0.88
Sustainability	Green credit share	+0.76

6.2 Composite QRFD index

Second-stage PCA on the six pillar scores yields PC1 explaining ~67% variance (illustrative). Regions with **balanced** performance (moderate-high scores across all pillars) tend to outrank regions that are deep but unstable, or inclusive but inefficient—consistent with literature that quality is multi-faceted rather than size-only.

Table 7. Illustrative regional QRFD ranks and clusters

Cluster (k-means on pillar scores)	Typical profile	Policy reading
C1 "Leaders"	High depth/efficiency, strong digital & green	Consolidate strengths; export best practices
C2 "Inclusive-digital risers"	High inclusion/digital, middling stability	Strengthen risk management & supervision
C3 "Scale-heavy but fragile"	High depth, weak stability/efficiency	De-risk balance sheets, improve cost discipline
C4 "Early-stage"	Low across pillars	Target inclusion & digital first; build enabling infra

7. Comparative Analysis: QRFD vs Existing Indices

The QRFD index targets *regional* disparities and explicitly adds **stability**, **digital**, and **green** pillars. By design it complements, rather than replaces, broader national indices:

- **IMF FD index** (national): broad multi-pillar benchmark but less granular regionally; QRFD can align on indicator families while providing within-country nuance.
- **Financial Inclusion composites** (national/regional): focus on access/usage; QRFD prevents inclusion from being mistaken for quality if efficiency or stability are weak.
- **Sustainability/green finance metrics**: QRFD internalizes green shares alongside mainstream pillars—a current policy priority.

8. Conclusion

A region-focused, PCA-based QRFD index offers a practical, transparent way to *measure what matters* in financial systems: balance among depth, efficiency, stability, inclusion, digitalization, and sustainability. It is complementary to national FD and FI indices, reveals within-country disparities, and translates naturally into a policy playbook. With official data plugged in, the QRFD can serve as a living dashboard for regulators and sub-national governments to monitor progress and course-correct.

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