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Innovation Financing under Constraints: A Principal Component and Cluster Analysis of Global Economies

Les contraintes de financement de l'innovation: une analyse en composantes principales et une classification des économies mondiales

ZERIOUH Radi
Economics and Management Ph.D.
Morocco

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Abstract

Financing innovation remains a major challenge in developing and emerging economies, where bank-dominated systems and institutional frictions intensify credit constraints. This study tests two hypotheses: (H1) credit rationing disproportionately restricts innovative projects, and (H2) institutional rigidity limits the translation of innovation efforts into performance. Using 87 country-year observations from the 2011–2022 World Bank Enterprise Surveys (35 variables), we conduct a Principal Component Analysis followed by K-means clustering. The first two components explain 58% of total variance, contrasting (i) financial constraint versus banking penetration and (ii) innovation intensity versus institutional rigidity. Three country profiles emerge: highly constrained economies with low innovation, intermediate economies hindered by fiscal and legal obstacles, and dynamic economies combining stronger financial systems with higher innovation. Crowdfunding appears as a differentiated corrective mechanism supporting financial inclusion in constrained economies, bypassing institutional rigidities in intermediate contexts, and acting as a cofinancing and market validation tool in dynamic ones. The results highlight the need for context-specific innovation-financing policies and confirm the complementary role of crowdfunding in alleviating structural imperfections in credit markets.

Keywords : Innovation financing, Credit market imperfections, Crowdfunding, Financial inclusion

Résumé

Le financement de l'innovation demeure un défi majeur dans les économies en développement et émergentes, où la prédominance bancaire et les frictions institutionnelles renforcent les contraintes de crédit. Cette étude teste deux hypothèses : (H1) le rationnement du crédit pénalise davantage les projets innovants, et (H2) la rigidité institutionnelle limite la transformation des efforts d'innovation en performances. À partir de 87 observations pays-année issues du WBES (2011–2022, 35 variables), nous appliquons une Analyse en Composantes Principales suivie d'un clustering K-means. Les deux premières composantes expliquent 58 % de la variance totale et opposent : (i) contrainte financière et pénétration bancaire, et (ii) intensité d'innovation et rigidité institutionnelle. Trois profils de pays émergent : économies fortement contraintes et peu innovantes, économies intermédiaires freinées par des obstacles fiscaux et juridiques, et économies dynamiques combinant un système financier plus robuste et une innovation élevée. Le financement participatif apparaît comme un mécanisme correctif différencié : inclusion financière dans les économies contraintes, contournement des rigidités dans les économies intermédiaires, et cofinancement/validation de marché dans les économies dynamiques. Les résultats soulignent la nécessité de politiques adaptées de financement de l'innovation.

Mots clés : Financement de l'innovation, imperfection du marché de crédit, Crowdfunding, Financial inclusion

Introduction

Over the past two decades, the issue of financing innovation has become a central concern for both academic research and public policy. Innovation, understood as the ability to generate new products, processes or business models, is a key driver of productivity and competitiveness at both the firm and national levels. However, the economic literature consistently shows that innovative projects face specific financing constraints rooted in structural imperfections in credit markets. Banks and traditional investors, faced with uncertainty, information asymmetry and limited tangible collateral, tend to ration credit and restrict the allocation of resources to innovation.

This challenge is even more pronounced in developing and emerging economies where financial systems are less diversified and heavily dominated by the banking sector. Small and medium-sized enterprises, which form the backbone of the productive fabric, face restrictive financing conditions such as excessive collateral requirements, unfavorable interest rates and lengthy or uncertain approval processes. These constraints interact with institutional obstacles including corruption, political instability, excessive taxation and judicial inefficiency. Together, these factors undermine firms' capacity to invest in research and development, adopt new technologies and improve productivity.

In response to these persistent market failures, alternative financing mechanisms have gained attention. Crowdfunding, which has expanded rapidly over the past fifteen years, appears as a promising institutional response to financial constraints. By mobilizing contributions from a wide range of investors through digital platforms, it makes it possible to fund projects excluded from traditional financial circuits. As highlighted in Le crowdfunding de l'innovation (Zeriouh, 2022), this mechanism reduces information asymmetry through collective validation, strengthens intangible assets such as reputation and community engagement, and can serve as a credible signal for attracting institutional investors.

Crowdfunding should therefore be viewed not only as a substitute for bank financing but also as a complementary tool that can support innovation in contexts marked by financial or institutional constraints. Its relevance is evident both for startups and innovative SMEs confronted with credit rationing, and for intermediate economies where fiscal and legal rigidities inhibit innovation.

This study addresses the following research question: **To what extent do financial and institutional constraints determine countries' innovation**

capacity, and how can the identified profiles help interpret ex post the potential corrective role of crowdfunding?

To address this question, we rely on quantitative methods capable of capturing the multivariate relationships between financial constraints, institutional quality, innovation and economic performance. Principal Component Analysis provides this capacity by reducing a large set of correlated variables into a smaller number of structural dimensions while preserving essential information. Applied to a dataset of 87 country-year observations and 35 variables, PCA identifies the main axes that characterize economic environments in terms of financing access, institutional obstacles and innovation capacity. A subsequent K-means classification in the factorial space enables the construction of homogeneous country profiles and the interpretation of their implications for the role of crowdfunding.

Preliminary results highlight two dominant dimensions. The first axis contrasts economies facing strong financial constraints, reflected in high rejection of credit applications and heavy collateral requirements, with more bank-based economies where productive investment and research and development are more sustained. The second axis distinguishes innovative economies with high rates of product and process introduction from economies constrained by fiscal and legal obstacles. These findings align with the literature on credit rationing for innovation and reveal the structural interdependencies between finance, institutions and performance.

The K-means classification identifies three clusters: highly constrained economies with limited innovation, intermediate economies hindered by fiscal and regulatory barriers despite partial financial deepening, and dynamic economies combining stronger banking systems and higher innovation intensity. These profiles provide a basis for understanding the differentiated role of crowdfunding. In constrained economies, it operates as a tool for financial inclusion. In intermediate contexts, it helps circumvent institutional rigidities, particularly through transnational platforms. In dynamic economies, it reinforces community mobilization and accelerates the diffusion of innovative projects.

To guide the reader, the remainder of the article is structured as follows. The first section presents the epistemological and methodological approach, including the hypothetico-deductive framework and the rationale for combining PCA with K-means clustering. The second section outlines and interprets the empirical results. The third section offers an economic discussion of the findings with reference to the literature on credit market imperfections and

crowdfunding for innovation. The conclusion summarizes the main implications of the study and identifies avenues for future research.

1. Theoretical Framework: Credit Market Imperfections and the Specificity of Innovation

1.1. Credit Market Imperfections and the Rationing of Innovative Projects

In a perfect market, any profitable project should gain access to financing at the prevailing interest rate; in practice, however, effective access depends on collateral requirements that materialize information asymmetries. It is "virtually impossible to obtain bank financing without collateral," which constitutes a structural barrier for young entrepreneurs and startups, even though solvency does not necessarily reflect the fundamental value of the innovative project (ZERIOUH, 2022).

These imperfections result in dynamic inequalities: with comparable initial endowments, the absence of credit leverage restricts access to the same investment opportunities, so that initial wealth durably advantages some groups and penalizes others (Galor & Zeira, J, 1993). Thus, the imperfection of the credit market fuels income inequalities and the reproduction of social disparities, a diagnosis consistent with the analysis of Weeden & Grusky (2014) on the growing role of market failures in the formation of rents and institutional barriers.

On the microeconomic level, small and young firms are a priori more constrained: they have had little time to build trust-based relationships with lenders, whereas mature firms benefit from informational economies of scale (published accounts, completed audits). Bloch & Cœuré (1995) emphasize this asymmetry in access to credit depending on firm size, age, and dividend distribution.

Finally, the sectoral context exacerbates the tension: the return of confidence and technological transformation has multiplied innovative projects, while traditional investors maintain restrictive selection policies (Boyer, Chevalier, Léger, & Sannajust, 2016; Rifkin, 2012), highlighting the urgency of financial mechanisms suited to converting innovation into socio-economic value.

1.2. The Specificity of Innovation and the Limits of Classical Evaluation Methods

Innovation, in the Schumpeterian sense, consists of "new combinations" and differs from invention by its capacity to find a market or a use. It rarely occurs mechanically; the innovator acts under uncertainty, making decisions without complete information (Alter, 2000). The entrepreneur-innovator is driven more by action and commitment than by the sole pursuit of immediate profit (Schumpeter & Perroux, 1935).

This logic collides with dominant banking practices, centered on a legal-financial approach and solvency/collateral criteria (scoring, rating, liquidity and solvency ratios) that rely on routine benchmarks. Consequently, many innovative projects, intensive in intangible assets, uncertain in cash-flow trajectories, and potentially generating externalities, are involuntarily excluded from credit channels, particularly at the conception and seed stages.

In other words, the evaluation tools designed for the "classical firm" fail to capture either entrepreneurial intuition or the potential social value of the project. As Alter (2000) notes, "if the entrepreneur waited until sufficient information was available before acting, he would never act"; likewise, the banking institution that only measures solvency overlooks the novelty and economic and social impact of innovation.

1.3. Crowdfunding as a Corrective Lever for Imperfections

1.3.1. Logic and Emergence

Following the logic of crowdsourcing (Howe, 2006; Belleflamme, Lambert, & Schwienbacher, 2010), crowdfunding is defined as an "open call" via the Internet to obtain financial resources in the form of donation, reward/voting rights, loan, or equity participation (Lambert & Schwienbacher, 2010). Mollick (2014) specifies that it consists of efforts by actors (entrepreneurs, groups) to finance their initiatives through small contributions from a large number of individuals, without conventional financial intermediation.

Its growth can be explained by (1) the financing gap at the early stage, with traditional investors favoring less risky established firms (Pierrakis & Collins, 2012), and (2) disintermediation enabled by Web 2.0, which converts the entrepreneur's social capital into financial capital.

1.3.2. Idea based valuation and the wisdom of crowds

Contrary to bank evaluation based on solvency and collateral, crowdfunding evaluates the idea, novelty, commitment of the entrepreneur, and economic and social impact, the relationship is no longer purely financial but also cognitive/social; allocation is no longer decided by a single expert but by the crowd.

On evaluation quality, Mollick & Nanda (2015) show: (1) statistical harmony between crowd decisions and expert evaluations; (2) in case of disagreement, the crowd more often funds projects rejected by experts; (3) in the long term, no qualitative/quantitative difference appears between projects supported by both versus by the crowd alone. These results refute the "irrationality of crowds" and highlight an extraction of information based on different attributes of the process.

The wisdom of crowds (Surowiecki, 2004) lies in the aggregation of multiple judgments: "the average of judges beats the average judge" (Larrick, Mannes, Soll, & Krueger, 2012). In practice, aggregation maximizes available information, reduces the influence of extreme opinions, and increases credibility of the process (Budescu & Chen, 2014).

1.3.3. From informational efficiency to allocative efficiency :

Two implications follow: (i) collective evaluation reduces informational frictions and tends toward fundamental value; (ii) in the long term, trajectories financed by the crowd are not inferior to those supported by experts. Crowdfunding therefore achieves informational efficiency, a prerequisite for allocative efficiency: "capital allocation is efficient if markets mobilize savings and direct them to the uses with the highest social return" (Aglietta, 2005).

In short, the theoretical argument is clear: innovation faces credit rationing shaped by collateral requirements and evaluation routines that poorly capture intangibility, uncertainty, and novelty externalities, while crowdfunding reconfigures informational arbitration into a collective signal.

To put this tension to empirical test, we operationalize it in a framework structured around four complementary registers: banking financing conditions, firms' structural and growth dynamics, innovation intensity, and the environment of perceived obstacles. This framework is not a mere taxonomy: it organizes the factorial space of PCA in a coherent way to link financial constraints, firm profiles, innovation effort, and institutional frictions. The following section presents the variables retained in these registers and explains how their combination allows us to examine our research question: to what extent do financial and institutional constraints influence firms' innovation dynamics, and how can crowdfunding help correct credit market failures?

2. Methodology

2.1. Epistemological Stance and Methodological Positioning

This research adopts a realist-interpretative epistemological stance combined with a hypothetico-deductive logic. The quantitative analysis relies on the assumption that financial constraints, innovation indicators and institutional obstacles present underlying structural regularities that can be revealed through statistical techniques. Principal Component Analysis and K-means clustering are mobilized to identify these structures in a systematic and replicable manner. Their use follows established methodological standards, including tests of validity for PCA, examination of eigenvalues, and evaluation of the stability and interpretability of the retained components and clusters.

The interpretative dimension intervenes in a second stage, once the empirical profiles have been identified. Since crowdfunding is not directly observed in the dataset, its role is analyzed ex

post by confronting the country profiles with theoretical contributions on credit market imperfections and alternative financing mechanisms. This approach does not modify the statistical results but provides a structured framework for interpreting their economic implications.

This positioning allows the study to combine the rigor of empirical realism with an analytical reading of the mechanisms that may explain the observed configurations. It also preserves a clear distinction between the empirical structures revealed by the data and their theoretical interpretation within the literature on innovation financing and crowdfunding.

3. Data

The study is based on 87 observations (country-year) and 35 variables grouped into four dimensions (TABLE A1):

1. **Finance**: access to credit, banking conditions and financial behavior. These variables assess the degree of financial inclusion and the severity of financing constraints.
2. **Firm Profile**: growth, productivity and structural characteristics. These indicators provide information on firms' growth dynamics and internal structure.
3. **Innovation and Technology**: product and process innovation efforts and R&D expenditures. This block evaluates innovation effort and technological diffusion in the productive fabric.
4. **Biggest Obstacle**: perception of the main obstacles to development. This dimension reflects firms' subjective perceptions of structural constraints hindering competitiveness.

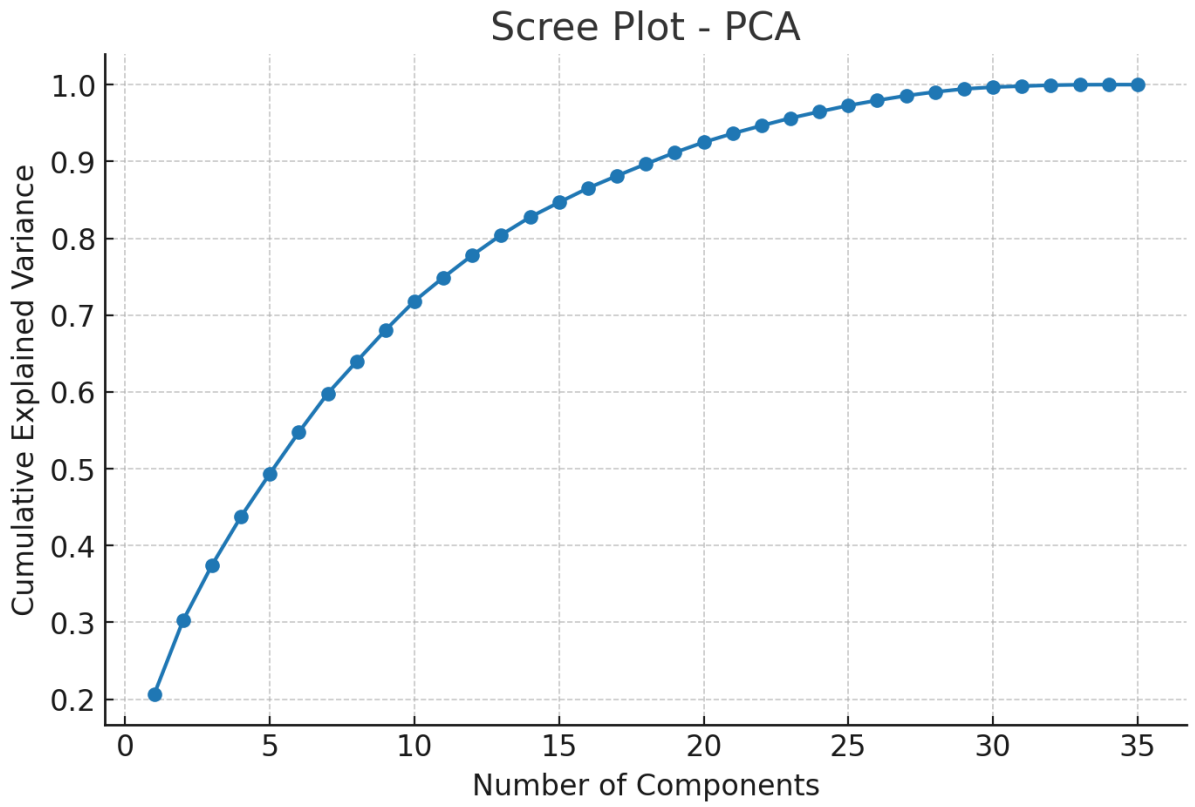
Each block contains a set of quantitative variables expressed as percentages of firms or as averages (rates, ages, durations). The unit of analysis is the country-year: each observation corresponds to a given country surveyed in a given year. The information is therefore treated in a **cross-sectional** way, with each country-year considered as an independent observation. The temporal dimension is not modeled explicitly, which constitutes a limitation of the study and should be kept in mind when interpreting the results.

The PCA is carried out on standardized data, followed by a K-means classification in the factorial space (PC1, PC2). This procedure makes it possible to reduce dimensionality, to highlight latent axes and to identify homogeneous country profiles in terms of financial constraints, innovation capacity, firm characteristics and perceived obstacles. The standardization of variables ensures that differences in units of measurement do not mechanically drive the results. The relevance of PCA and the choice of the number of

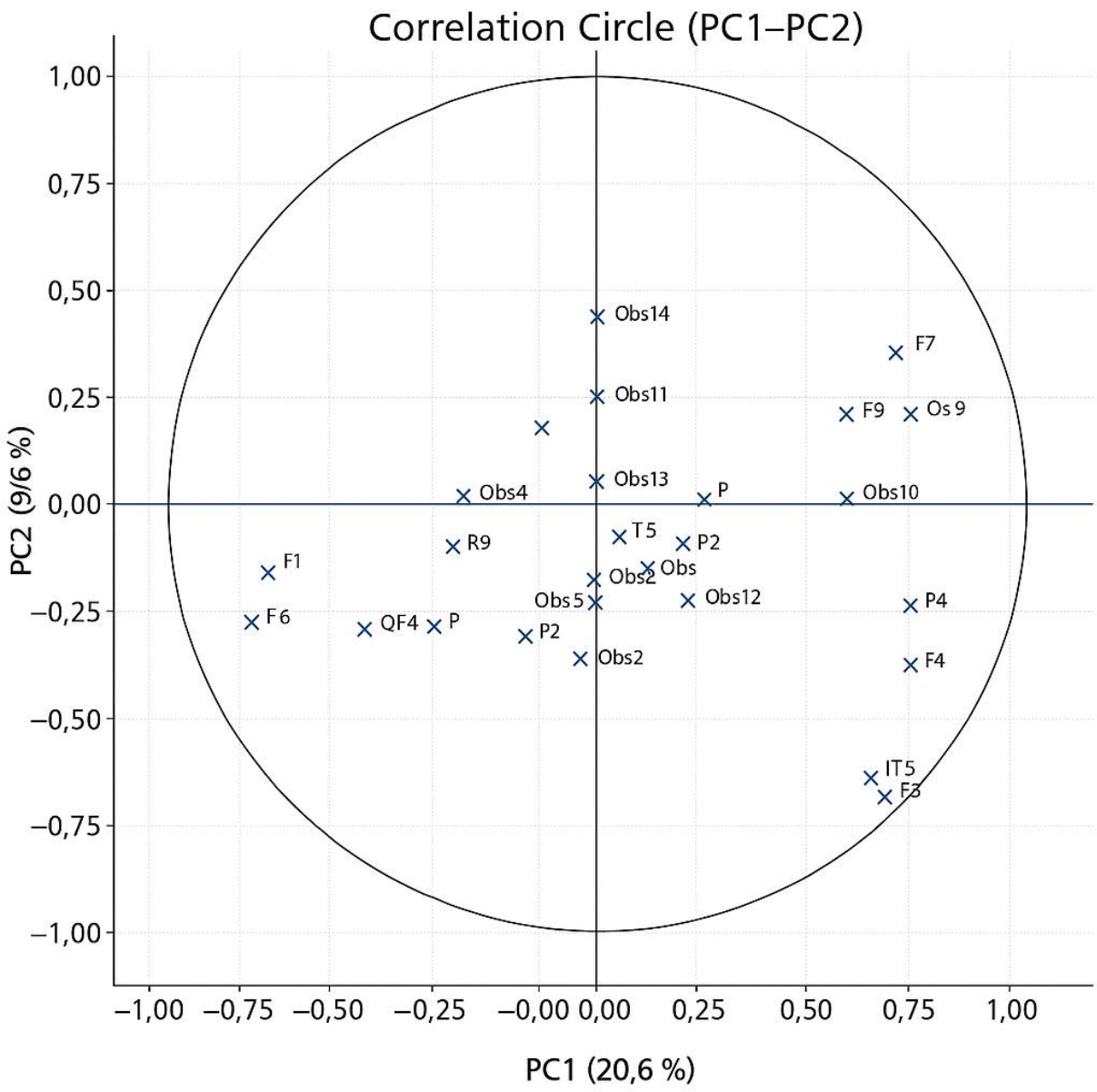
components and clusters are guided by usual statistical and interpretative criteria, which are detailed in the methodological appendix.

4. Results

The Principal Component Analysis yields a factorial structure where the first four axes account for 44 percent of total variance (PC1 = 20.6 percent, PC2 = 9.6 percent, PC3 = 7.2 percent, PC4 = 6.3 percent). The first ten components reach a cumulative variance of 71.8 percent, which indicates that relevant information extends beyond the sole PC1–PC2 plane. A detailed table of loadings for the first two components is presented in **Table A2**.

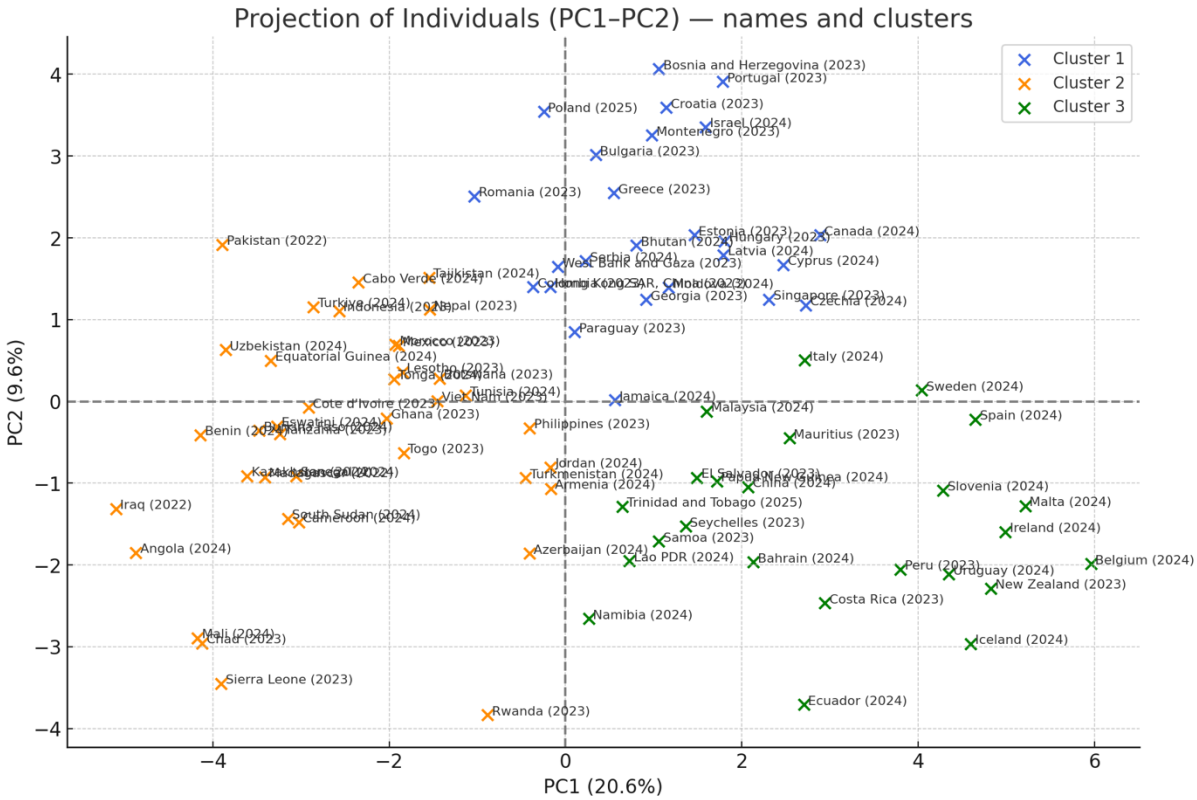


- **PC1 (20.6 percent)** contrasts:
  financial constraints (F1, F6, Obs1) with banking development and productive investment (F4, P4, IT3, IT4).
- **PC2 (9.6 percent)** distinguishes: economies with strong innovation dynamics (IT1, IT3, IT5, IT4) from contexts dominated by fiscal or legal obstacles (Obs14, Obs5).
- **PC3 and PC4** capture finer institutional distinctions related to corruption, political instability and infrastructure.



The correlation circle highlights two regularities:

1. **A strong alignment between innovation (IT) and firm profile (P)**, consistent with the idea that innovation capacity accompanies structural and productivity improvements.
2. **A clear opposition between financing constraints (F) and innovation variables**, reflecting the well-documented mechanism of credit rationing that limits innovative performance.



K-means Classification

To identify homogeneous profiles, a K-means algorithm with **k = 3** clusters was applied to the PCA scores (PC1–PC2). This partitioning reveals three distinct groups of economies (Figure 2). Descriptive means of key variables for each cluster are reported in **Table A3**.

The K-means classification identifies three groups:

- Cluster 1: intermediate economies, banked but hindered by fiscal/legal obstacles (e.g., Canada, Croatia).
- Cluster 2: constrained countries, with high dependence on financial and institutional obstacles, limited innovation (e.g., Chad, Sierra Leone).
- Cluster 3: dynamic economies, with strong banking penetration and sustained innovation (e.g., Belgium, Iceland, Spain).

1. Axis of Financial Constraints

The PC1 axis illustrates the presence of credit market imperfections: collateral requirements, heavy procedures, and banks' risk aversion. Economies with negative PC1 scores experience pronounced rationing, hampering their investment capacity.

2. Axis of Innovation and Performance

The PC2 axis contrasts countries with high innovation intensity (capable of introducing new products and processes) with those hampered by institutional obstacles (taxation, courts). This result confirms the importance of a favorable institutional environment for transforming innovation into growth.

Following the earlier analysis in Zeriouh (2022), crowdfunding can be interpreted ex post as a potential corrective mechanism for financial and institutional failures. Although not directly included as a variable in the dataset, its relevance emerges when the country profiles are compared with theoretical insights on alternative finance.

Crowdfunding:

- reduces information asymmetry through collective validation,
- values intangible assets such as reputation and community engagement in environments where banks prioritize material guarantees,
- provides a signaling effect that can attract institutional investors.

Within the PCA framework, crowdfunding appears particularly relevant for **Cluster 1**, where financial constraints slow innovation, and for **Cluster 2**, where institutional rigidities impede access to traditional financing. In both cases, its corrective potential aligns with the observed structural obstacles.

Les traitements statistiques ont été réalisés sous R (version 4.2.1, GUI 1.79 High Sierra build 8095) via RStudio, ainsi que sous Python à l'aide des bibliothèques pandas, numpy et scikit-learn. Sauf indication contraire, les algorithmes mobilisés correspondent aux implémentations standards de ces environnements.

5. Discussion

The Principal Component Analysis (PCA) conducted on the sample of countries reveals two structuring axes that help explain the configuration of financial constraints and innovation dynamics. The first axis contrasts economies characterized by severe credit frictions, bank rationing, loan rejections and heavy collateral requirements, with those where financial inclusion is more effective and productive investment accompanies banking penetration. The second axis distinguishes countries with a high intensity of innovation, marked by the introduction of new products and processes and by R&D expenditures, from those where taxation, regulatory burdens and judicial distrust constitute significant impediments. Together, these axes outline a factorial geography from which three country profiles emerge.

It is important to emphasize that these profiles are derived exclusively from WBES variables, which capture financial conditions, institutional obstacles and innovation characteristics. Crowdfunding does not appear in the dataset, and its role is therefore not measured empirically, but interpreted ex post on the basis of the structural configurations uncovered by the PCA. This interpretative exercise aims to situate crowdfunding within a broader analytical framework, not to infer any causal relationship between crowdfunding and the observed country characteristics.

The first cluster groups countries that, despite relatively effective banking penetration, face persistent legal and fiscal obstacles. In these contexts, access to credit is not the primary concern. The high levels of non-application for loans reflect not an absence of investment projects, but a rational avoidance of institutional frictions such as excessive taxation, unpredictable judicial processes and administrative delays.

Within this landscape, crowdfunding can be understood prospectively as a mechanism of disintermediation. Transnational platforms offer firms a way to bypass local institutional rigidities by mobilizing external communities of investors in standardized digital environments. The value of crowdfunding here lies less in substituting for bank credit than in reducing transaction costs, signaling market interest and leveraging community support. This interpretation highlights how crowdfunding could complement traditional finance rather than replace it.

The second cluster gathers the most constrained economies. High rejection rates, widespread rationing and the perception of finance as a dominant obstacle indicate the presence of strong credit market imperfections. Traditional evaluation mechanisms, largely based on collateral and predictable revenue streams, tend mechanically to exclude innovative or early-stage projects.

In such environments, crowdfunding could function as a lever of financial inclusion. By mobilizing dispersed contributors, entrepreneurs can access funding that banks refuse. The aggregation of individual contributions provides an information signal about demand and partially mitigates asymmetric information. A successful campaign might also serve as a stepping stone toward bank financing or institutional investment. However, this remains a potential role, not an observed behavior in the WBES data. It is therefore more appropriate to present crowdfunding here as a possible trajectory for alleviating exclusion, rather than a demonstrated empirical effect.

At the same time, these economies are often characterized by digital divides, weak investor protection and limited regulatory oversight, which may restrict the reach or safety of

crowdfunding practices. Any prospective interpretation must take these constraints into account.

The third cluster occupies the most favorable region of the factorial plane, combining access to credit, financial inclusion and high innovation intensity. These economies illustrate a virtuous circle: investment supports innovation, innovation raises productivity and growth, and a supportive institutional framework reinforces this dynamic.

In such contexts, crowdfunding might play a different role, oriented toward co-financing, acceleration and market validation. Pre-sale campaigns allow firms to test market traction rapidly, reduce uncertainty, attract international communities and accelerate commercialization. Equity and lending models help diversify funding sources, broaden the investor base and reinforce project legitimacy. Here, the value of crowdfunding lies less in access to capital and more in speed, visibility and community-driven reputation effects. Again, these are prospective mechanisms, inferred from theoretical literature and structural patterns, not from direct empirical evidence within the WBES dataset.

The factorial structure shows a sharp contrast between second cluster and third cluster economies. The former combine credit constraints with weak innovation dynamics, while the latter couple banking depth with strong innovative momentum. The first cluster stands in an intermediate position: banking inclusion is relatively effective, but institutional rigidities limit innovation potential.

A notable paradox concerns the high values of F7 (non-application for credit) in institutionally burdensome contexts. Rather than signaling an absence of financing needs, it reflects strategic avoidance and greater reliance on self-financing or non-traditional channels. Crowdfunding can thus be seen as revealing latent financing demand that remains invisible to banks.

Nevertheless, crowdfunding is not a universal remedy, and its expansion raises challenges that are particularly acute in constrained economies. These include:

• regulatory fragility and risks of fraud
• unequal digital access
• herd behavior and volatility in investor sentiment
• insufficient investor protection, especially in equity and lending models

These limitations highlight the need for appropriate regulatory frameworks and capacity-building measures if crowdfunding is to complement financial systems effectively.

The PCA illuminates how financial constraints, institutional obstacles and innovation dynamics intersect. Three prospective trajectories emerge:

1. financial exclusion, where crowdfunding may foster financial inclusion (second cluster)
2. banking penetration hindered by institutions, where crowdfunding may operate as a cross-border bypass mechanism (first cluster)
3. innovative ecosystems, where crowdfunding may complement traditional financing through co-financing and community mobilization (third cluster)

The central point is that crowdfunding does not have a single function. Its potential varies according to the structural characteristics of economies. By linking factorial analysis with theoretical insights on credit market imperfections and alternative finance, this discussion proposes a prospective analytical framework rather than an empirical demonstration of the effects of crowdfunding.

Conclusion

The Principal Component Analysis conducted in this study made it possible to highlight the underlying structures that organize financing and innovation dynamics in a panel of countries. The results reveal two major tensions: first, the opposition between economies strongly constrained by credit market frictions and those with more fluid access to bank financing; second, the contrast between innovative and high-performing environments and those penalized by persistent institutional obstacles. This dual factorial reading confirms a structural interdependence between access to financing, innovation capacity and the quality of the institutional environment.

The first factorial axis captures the gradient of financial constraint. Countries positioned on the negative side are marked by heavy procedures, high collateral requirements, elevated rejection rates and a widespread perception of finance as a major obstacle. Conversely, positive scores reflect more advanced banking penetration and a greater propensity to invest in productive capital and research and development. This dimension illustrates the influence of credit market imperfections on firms' investment dynamics.

The second axis highlights the articulation between innovation and the institutional environment. Economies characterized by regular product and process introduction and sustained R&D intensity oppose those where fiscal, judicial and administrative rigidities constrain productive dynamism. This axis illustrates the complementarity between innovation effort and institutional quality: creativity unfolds fully only when the regulatory framework does not impose excessive transaction costs.

The K-means classification complements this analysis by distinguishing three profiles of economies. The first cluster groups contexts marked by strong credit rationing and low innovation intensity. The second cluster brings together intermediate countries, relatively banked but heavily penalized by fiscal and legal constraints. The third cluster corresponds to dynamic economies where banking penetration and innovation converge to support competitiveness.

These results echo the literature on credit market imperfections, which emphasizes that innovative projects, often intangible, risky and with long return horizons, are particularly exposed to banking rationing. In this perspective, crowdfunding appears as a relevant mechanism. It helps reduce information asymmetry by aggregating dispersed signals of interest, values intangible assets such as creativity, reputation or community engagement and reinforces the credibility of projects. However, it is essential to recall that WBES data do not contain any direct variables relating to crowdfunding. Its role is therefore interpreted ex post, in light of the structural profiles revealed by the analysis and the theoretical literature, rather than empirically demonstrated.

Thus, in the first cluster, crowdfunding can help bypass institutional rigidities through cross-border platforms. In the second cluster, it could act as a tool of financial inclusion for projects rationed by banks. In the third cluster, it may serve as an accelerator, enabling co-financing, pre-sales and rapid market validation.

From a policy perspective, these results suggest that public authorities should establish clear regulatory frameworks to integrate crowdfunding into national innovation strategies. For firms, crowdfunding constitutes a potential sequential strategy: securing collective validation before seeking institutional investors. For traditional funders, it can serve as a complementary instrument for risk sharing and identifying high-potential projects.

Despite its contributions, the study presents several limitations that should be acknowledged:

- The dataset is cross-sectional by construction: country-year observations do not allow dynamic analysis or causality inference.
- PCA is a descriptive method, which highlights structural patterns but cannot establish causal relationships between variables.
- The first two axes capture only about 30 percent of total variance, which requires caution when interpreting the factorial plane.
- The analysis does not include direct measures of crowdfunding; its role is inferred theoretically and prospectively.

- Cluster results depend on the chosen number of groups and on the PCA space, which may vary with alternative specifications.

These limitations do not undermine the relevance of the structural patterns identified but delimit the scope of the conclusions.

Several extensions could deepen and refine the insights provided by this work:

- Incorporating country-level data on crowdfunding platforms, volumes raised or regulatory frameworks, in order to empirically test the prospective roles suggested here.
- Using panel data econometrics (fixed effects, dynamic models, instrumental variables) to study the causal links between financial constraints, institutions and innovation.
- Applying regional comparative approaches (Sub-Saharan Africa, MENA, Eastern Europe) to identify specific trajectories and contextual factors.
- Integrating alternative multivariate techniques, such as structural equation modelling, multiple factor analysis or latent class models, to test the robustness of the typology.

Ultimately, this research affirms that financial and institutional constraints remain major barriers to innovation financing, but also suggests that crowdfunding may constitute a differentiated lever depending on country profiles. By revealing the structural configurations of constraints and innovation dynamics, PCA anchors this reflection in empirical regularities and highlights the need for tailored policies to foster innovation through both traditional and alternative financing channels.

Appendix :

Table A1 : Identifiers and description of variables

	Identifier	**Variables**
Finance	**F1**	Percent of firms that are fully credit constrained
	F2	Percent of firms that are partially credit constrained
	F3	Percent of firms with a checking or savings account
	F4	Percent of firms with a bank loan/line of credit
	F5	Average proportion of loans requiring collateral (%)
	F6	[B-READY] Percent of firms reporting unfavorable rates, collateral, or procedures as main reason for not applying for loans
	F7	Percent of firms not needing a loan
	F8	[B-READY] Average days to receive a decision on loan application

	F9	Percent of firms whose recent loan application was rejected
Firm Profile	**P1**	Average real annual sales growth (%)
	P2	Average annual employment growth (%)
	P3	Average real annual labor productivity growth (%)
	P4	Percent of firms buying fixed assets
	P5	Average capacity utilization (%)
	P6	Average age of the establishment (years)
Innovation and technology	**IT1**	Percent of firms that introduced a new /service over last 3 years
	IT2	Percent of firms whose new product/service is also new to the main market
	IT3	Percent of firms that introduced a process innovation over last 3 years
	IT4	Percent of firms that spend on R&D in product the last fiscal years
	IT5	[B-READY] Percent of firms that introduced a new product/service and process over last 3 years, and spent on R&D over last fiscal year (excluding small firms)
Biggest Obstacle	**Obs1**	Percent of firms choosing access to finance as their biggest obstacle
	Obs2	Percent of firms choosing access to land as their biggest obstacle
	Obs3	Percent of firms choosing business licensing and permits as their biggest obstacle
	Obs4	Percent of firms choosing corruption as their biggest obstacle
	Obs5	Percent of firms choosing courts as their biggest obstacle
	Obs6	Percent of firms choosing crime, theft and disorder as their biggest obstacle
	Obs7	Percent of firms choosing customs and trade regulations as their biggest obstacle
	Obs8	Percent of firms choosing electricity as their biggest obstacle
	Obs9	Percent of firms choosing inadequately educated workforce as their biggest obstacle
	Obs10	Percent of firms choosing labor regulations as their biggest obstacle
	Obs11	Percent of firms choosing political instability as their biggest obstacle
	Obs12	Percent of firms choosing practices of the informal sector as their biggest obstacle
	Obs13	Percent of firms choosing tax administration as their biggest obstacle
	Obs14	Percent of firms choosing tax rates as their biggest obstacle
	Obs15	Percent of firms choosing transportation as their biggest obstacle

World Bank Enterprise Surveys (WBES), Enterprise Analysis Unit, Development Economics Global Indicators Group, July 21, 2025, www.enterprisesurveys.org.

Table A2: Loadings of Variables on the First Two Principal Components (PC1 and PC2)

	PC1	PC2
F1	-0,29664	-0,11295
F2	-0,21208	-0,16612
F3	0,195846	0,117448
F4	0,259448	0,026937
F5	-0,16977	-0,15253
F6	-0,31768	-0,15494
F7	0,24172	0,203715
F8	-0,02277	-0,09752
F9	-0,15276	-0,04639
P1	0,052778	-0,04981
P2	-0,07775	-0,1597
P3	0,085865	0,021735
P4	0,241059	-0,13492
P5	-0,04778	0,111849
P6	0,257731	0,037527
IT1	0,219327	-0,38864
IT2	0,058549	-0,06343
IT3	0,22969	-0,37376
IT4	0,236818	-0,22459
IT5	0,218961	-0,3553
Obs1	-0,22671	-0,16507
Obs2	-0,04696	-0,22626
Obs3	0,034469	-0,10386
Obs4	-0,11841	0,012716
Obs5	0,008243	0,233884
Obs6	-0,03862	-0,11915
Obs7	-0,04913	-0,01294
Obs8	-0,13918	-0,12243
Obs9	0,25653	0,130338
Obs10	0,180841	-0,02804
Obs11	0,011995	0,133283
Obs12	0,070071	-0,12865
Obs13	-0,01565	0,033787
Obs14	0,029562	0,251841
Obs15	0,03393	-0,15025

Table A3: Descriptive Means of Key Variables by Cluster

Cluster	1	2	3
F1	5,670833	7,732	24,58421
F2	10,95833	10,024	22,95789
F3	95,05833	95,628	83,97895
F4	48,875	43,508	24,75
F5	56,82917	54,992	77,67105
F6	10,5125	12,816	36,67895
F7	59,70417	61,436	39,23947
F8	27,8875	22,732	25,52368
F9	3,766667	3,632	11,53947
P1	10,33333	7,104	7,55
P2	5,8625	4,468	7,592105
P3	4,916667	3,084	0,881579
P4	52,61667	41,22	28,56053
P5	72,85833	74,432	75,30789
P6	24,34583	20,488	15,78684
IT1	52,50833	13,828	19,74737
IT2	60,56667	55,852	55,31316
IT3	36,8625	8,732	11,72632
IT4	27,70833	16,256	11,59474
IT5	13,8125	1,572	3,171053
Obs1	12,06667	9,232	28,53158
Obs2	4,620833	1,04	4,352632
Obs3	4,341667	2,7	3,255263
Obs4	3,320833	3,724	6,231579
Obs5	0,358333	1,064	0,484211
Obs6	6,2375	2,916	5,318421
Obs7	2,945833	2,648	3,547368
Obs8	4,545833	4,456	8,097368
Obs9	19,8375	21,372	4,442105
Obs10	7,083333	4,548	1,742105
Obs11	7,2	14,64	8,084211
Obs12	9,958333	6,704	7,973684
Obs13	3,075	2,78	3,202632
Obs14	10,2375	19,94	11,67632
Obs15	4,179167	2,2	3,052632

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