

Drivers of innovation and competitiveness in small and medium-sized enterprises: a comprehensive analysis of the Latin American and Caribbean region

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Abstract

This study analyses the key drivers of innovation and competitiveness in small and medium-sized enterprises (SMEs) in Latin America and the Caribbean between 2006 and 2023. Using panel data regression (fixed and random effects) and machine learning models, the authors identify the most significant enablers of SME innovation. In addition, they find that political stability plays a positive role, while inflation and corruption significantly constrain performance. The study integrates classical innovation theory with emerging insights from Asian economies and highlights the role of political culture in shaping SME resilience.

Keywords

Small and medium enterprises, technological innovations, competitiveness, measurement, data analysis, econometric models, economic statistics, economic development, Latin America and the Caribbean

JEL classification

O31, O32, L25, O54, C23

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I. Introduction

Small and medium-sized enterprises (SMEs) are vital components of the economic landscape in the Latin American and Caribbean region, contributing significantly to employment, innovation and gross domestic product (GDP) (Phillips et al., 2024). According to definitions commonly used by the World Bank and regional statistical agencies, SMEs typically have fewer than 250 employees and an annual turnover below national thresholds. For example, in several Latin American and Caribbean countries, a small enterprise may be defined as having between 10 and 49 employees, and medium-sized firms between 50 and 249. These definitions, while varying slightly by jurisdiction, offer a consistent basis for comparative regional analysis. SMEs often exist along a spectrum of structures, from formal to informal, which makes their dynamics particularly complex in the regional context.

Moreover, SMEs are not a monolithic group, but vary widely by sector, with strong representation in manufacturing, agriculture, retail and, especially, services. Informal SMEs—often excluded from official registries—play an especially vital role in employment and income generation in the economies of the Latin American and Caribbean region. This sectoral diversity has implications for innovation strategies and access to resources, as firms in different industries face distinct regulatory, technological and market barriers (Chung and Tan, 2017).

Despite their critical role, SMEs in the region face persistent and interlinked challenges. These include limited access to financing mechanisms, inadequate physical and digital infrastructure, skill shortages, high informality and complex bureaucratic environments (Altman and Sabato, 2023). These structural impediments weaken the capacity of SMEs to engage in innovation and limit their competitive edge. Innovation, broadly defined as the implementation of new or significantly improved products, processes, marketing methods or organizational structures, is essential for long-term productivity gains and economic diversification (Viglioni et al., 2020). Competitive SMEs can adapt to changing global markets, scale effectively and contribute to structural economic transformation, in particular in middle-income economies seeking to reduce reliance on commodity exports (Spinola, 2023).

The Latin American and Caribbean region presents a unique ecosystem for SME development, marked by a combination of institutional volatility, economic polarization and dynamic entrepreneurial cultures. Key contextual factors, such as political instability, weak rule of law, corruption, economic cycles of boom and bust, and uneven technological adoption patterns continue to shape the innovation trajectories of SMEs (Spinola, 2023; Díaz, 2024). In this environment, the capacity for SMEs to innovate and remain competitive hinges not only on firm-level strategies but also on the broader structural context.

The present study examines SME innovation and competitiveness in this turbulent yet promising landscape. There is a notable gap in the literature, with most prior research focusing on SMEs in high-income economies or large emerging markets such as China and India (Sharif et al., 2024). However, recent comparative research from Asia offers valuable insights for understanding SMEs in Latin America and the Caribbean. For instance, Chen et al. (2017) found that disruptive innovation among Chinese SMEs was shaped by unique institutional factors such as government-business linkages and industrial clustering. Similarly, Sharma (2014) identified the critical role of policy-driven research and development (R&D) incentives and regional economic networks in fostering innovation by SMEs in India.

These studies underscore that innovation in emerging markets cannot be entirely understood through Western theoretical models alone, and that regional characteristics—such as informality, State capacity and sociocultural norms—must be integrated into the analysis. This research responds to those insights by situating SME innovation within the institutional and developmental context of Latin America and the Caribbean.

The core research question guiding this study is: what are the key drivers of innovation and competitiveness in SMEs in the region, and how do these factors influence economic diversification?

Addressing this question is not only academically relevant but also urgent for policy. The objective is twofold: (i) to identify and evaluate the factors that facilitate or hinder innovation within SMEs, and (ii) to assess how these drivers influence SME competitiveness and broader economic diversification outcomes in the region.

Data for this research² are drawn from several internationally recognized sources, including the World Bank's World Development Indicators, the Global Innovation Index, the International Monetary Fund (IMF) and national statistical offices. This supports robust longitudinal analysis using comparable socioeconomic indicators in Latin America and the Caribbean. The data set includes both large economies —such as Brazil, Mexico and Argentina— and smaller ones —such as Belize, Grenada and Saint Lucia— thus capturing the full spectrum of regional diversity (Phillips et al., 2024). The time frame 2006–2023 encompasses periods of growth, financial crises, commodity price shocks and technological diffusion waves, all factors that deeply affect SME innovation and performance.

Key variables include access to finance (Altman and Sabato, 2023), the regulatory environment (Phillips et al., 2024), technological infrastructure (Viglioni et al., 2020), education levels (Diawati et al., 2024), market size (Gazé Holguin et al., 2023), trade openness (Phillips et al., 2024), per capita GDP (Spinola, 2023), inflation rates (Altman and Sabato, 2023), and political stability and corruption (Spinola, 2023). Innovation outputs are measured through R&D expenditure and patent registrations, while SME competitiveness is captured using growth rates and market share metrics.

To examine these relationships, the authors employ two complementary analytical strategies: (i) *panel data regression models*: fixed effects and random effects models are used to control for time-invariant differences and estimate the effects of macroeconomic, institutional and structural factors over time (McManus, 2015; Bell and Jones, 2015); and (ii) *machine learning models*: random forest and gradient boosting machines are deployed to detect complex, non-linear relationships and to rank the relative importance of each variable (Rigatti, 2017; Natekin and Knoll, 2013). These models are particularly useful in identifying latent patterns in high-dimensional data.

By integrating econometric and machine learning approaches, this study offers a regionally grounded, data-rich account of the drivers that shape SME innovation and competitiveness in the region.

The remainder of this paper is structured as follows: section II offers a literature review that explores existing research on SME innovation and competitiveness. This is followed by an explanation of the theoretical framework in section III and the hypothesis for the work in section IV. Section V, on the methodology, presents the research design and data sources used. Section VI sets forth the results, reporting the findings from econometric and machine learning models. Section VII offers concluding remarks, including policy recommendations, a discussion linking empirical results to theory and exploring the role of political culture and resilience, and, finally, limitations of the study and suggestions for future research to respond to the reviewers' comments.

II. Literature review

1. SME innovation

SME innovation refers to the implementation of new or significantly improved products, processes, marketing methods or organizational practices by SMEs. Innovation in SMEs is critical, as it enhances productivity, competitive advantage and overall economic growth (Kaminski, 2011; Ślędzik, 2013).

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The determinants of innovation in SMEs have been widely studied globally, with various factors identified as critical drivers. Access to finance is often cited as a significant enabler of innovation. Financial resources allow SMEs to invest in R&D, acquire new technologies and enter new markets. Altman and Sabato (2023) emphasize that capital markets play a crucial role in funding SME innovation, particularly in regions with well-developed financial infrastructure. Another crucial factor is the regulatory environment.

A supportive regulatory framework can reduce the barriers to entry and operation for SMEs, encouraging innovation. Phillips et al. (2024) argue that a stable and predictable regulatory environment fosters a conducive setting for innovation by reducing uncertainty and encouraging investment.

Technological infrastructure is also essential for SME innovation. In their systematic literature review on innovation in Latin America and the Caribbean, Viglioni et al. (2020) found that access to modern technologies significantly impacts SME innovation capacity. They argue that the availability of technological resources enables SMEs to streamline operations, improve product quality and enhance market competitiveness.

Human capital, in particular the education level of the workforce, is another determinant of innovation. Diawati et al. (2024) discuss how higher education levels correlate with greater innovation capabilities in SMEs. Educated employees are better equipped to develop and implement innovative solutions and thereby drive organizational growth.

Market size and trade openness are also influential. Larger markets provide more opportunities for SMEs to scale their innovations and achieve economies of scale. Open trade policies facilitate access to international markets and technologies, further boosting innovation. Gazé Holguin et al. (2023) argue that trade openness allows SMEs to learn from international competitors and adopt best practices in order to enhance their innovative capabilities.

In the context of the Latin American and Caribbean region, additional factors, such as political stability, corruption levels, and macroeconomic conditions also play significant roles. Spinola (2023) notes that political instability and economic volatility can hinder innovation by creating an uncertain business environment. Conversely, stable political conditions and low corruption levels are conducive to long-term investments in innovation.

While the existing literature provides a comprehensive overview of the determinants of SME innovation, several gaps remain. For instance, most studies have focused on developed countries or larger emerging economies, with limited attention being afforded to smaller nations in Latin America and the Caribbean (Marullo et al., 2024). In addition, more empirical studies are needed to examine the interplay between different determinants of innovation, such as how technological infrastructure and access to finance jointly impact SME innovation (Sharif et al., 2024). These factors can significantly shape the innovation landscape but are not sufficiently addressed in current research. Moreover, the existing literature often overlooks the role of contextual factors unique to the Latin American and Caribbean region, such as cultural influences and regional economic integration (Katz, 2023).

In view of these gaps, this article aims to provide a comprehensive analysis of the key drivers of SME innovation and competitiveness in Latin America and the Caribbean. Applying advanced analytical models to a diverse sample of 50 countries and territories, this study seeks to fill the existing gaps and contribute to the literature by offering nuanced insights into the regional dynamics of SME innovation. This research will thus provide valuable information for policymakers, business leaders and academic researchers, with a view to offering practical recommendations for fostering SME innovation and enhancing competitiveness in the region.

2. Competitiveness in SMEs

Competitiveness in SMEs refers to their ability to compete effectively in the market, by maintaining or increasing market share, profitability and long-term sustainability. Competitiveness is influenced by a variety of factors, including the firm's internal capabilities and the external environment in which it operates (Kaczmarek, 2022). Several factors influence SME competitiveness. One of the main ones is innovation, which enables SMEs to develop unique products and services, improve processes and enter new markets (Śledzik, 2013). Innovation drives competitiveness by enhancing productivity and creating value for customers (Kaminski, 2011).

Access to finance is another critical factor: SMEs that can secure funding are better positioned to invest in new technologies, expand operations and improve efficiency. Altman and Sabato (2023) highlight the importance of capital markets in providing the necessary resources for SMEs to enhance their competitiveness. Adequate financing enables SMEs to implement strategic initiatives to improve their market position.

The regulatory environment also plays a significant role. A supportive regulatory framework reduces the barriers to entry and operation, allowing SMEs to compete more effectively. Phillips et al. (2024) argue that a stable and predictable regulatory environment fosters competitiveness by reducing compliance costs and encouraging investment. This is particularly important in regions where regulatory hurdles can stifle business growth.

Technological infrastructure is also essential for SMEs to remain competitive. Viglioni et al. (2020) emphasize that access to advanced technologies enables SMEs to improve their processes, enhance product quality and reach new customers. Technology adoption is a key driver of competitiveness, as it allows SMEs to operate more efficiently and respond quickly to market changes.

Human capital is another vital determinant. A skilled and knowledgeable workforce can drive innovation and operational excellence. Diawati et al. (2024) discuss how higher education levels correlate with improved competitiveness in SMEs. Well-educated employees are better equipped to develop innovative solutions and improve business practices.

Market size and trade openness also influence competitiveness. Larger markets provide more opportunities for growth and economies of scale. Open trade policies facilitate access to international markets and technologies, which can enhance the competitive edge of SMEs. Gazé Holguin et al. (2023) argue that trade openness allows SMEs to learn from international competitors and adopt best practices, thereby improving their competitiveness.

Macroeconomic and other factors, such as per capita GDP, inflation rates, political stability and corruption levels, also impact SME competitiveness. Spinola (2023) notes that stable economic conditions and low corruption levels create a conducive environment for SMEs to thrive. Conversely, economic volatility and high levels of corruption can hinder competitiveness by creating uncertainty and increasing operational costs.

While the existing literature provides valuable insights into the factors influencing SME competitiveness, several gaps remain. Many studies have focused on large firms or developed countries, with limited attention being afforded to SMEs in Latin America and the Caribbean (Marullo et al., 2024). More empirical research is also needed on the interplay between different competitiveness factors, such as how technological infrastructure and human capital jointly impact SME competitiveness (Sharif et al., 2024). In addition, the role of contextual factors unique to the region, such as cultural influences and regional economic integration, is often overlooked (Katz, 2023).

III. Theoretical framework

Innovation is a critical driver of economic development and competitiveness in SMEs. Schumpeter's theory of innovation posits that economic development is driven by innovative activities that disrupt existing market structures and create new opportunities for growth (Śledzik, 2013). Schumpeter emphasized the role of the entrepreneur as the catalyst for innovation, introducing new products, processes and business models that spur economic dynamism. This theory underlines the importance of fostering an entrepreneurial culture within SMEs to drive innovation and competitiveness (Piore, 2007).

Another relevant framework is the diffusion of innovations theory put forward by Everett Rogers, which explains how, why and at what rate new ideas and technologies spread within and between societies (Rogers et al., 2014). According to Rogers, the adoption of innovations follows a bell-shaped curve, with innovators and early adopters leading the way, followed by the early majority, late majority and laggards. Understanding this diffusion process is crucial for SMEs as it highlights the importance of targeting early adopters to gain market traction and accelerate the uptake of innovative solutions (Kaminski, 2011).

Competitiveness in SMEs can be analysed using Porter's diamond model, which identifies four determinants that contribute to national and firm-level competitive advantage: factor conditions, demand conditions, related and supporting industries, and firm strategy, structure and rivalry (Ketels, 2006). Porter's framework emphasizes the role of a conducive environment in fostering competitive businesses. For SMEs, this means that access to skilled labour, sophisticated local demand, supportive industries and intense local competition can drive innovation and enhance competitiveness (Bakan and Doğan, 2012). Porter's model also highlights the significance of government and chance events in shaping competitive advantage. Government policies that support R&D, provide incentives for innovation and create a stable business environment are crucial for SME competitiveness (Özgen et al., 2011). Unexpected developments, such as technological breakthroughs or shifts in consumer preferences, may also create opportunities for SMEs to innovate and gain a competitive edge.

To comprehensively understand the dynamics of SME innovation and competitiveness, an integrated theoretical framework combining innovation and competitiveness theories is proposed here. This model leverages Schumpeter's and Rogers's insights on the importance of entrepreneurial activities and the diffusion of innovations, alongside Porter's diamond model, which provides a holistic view of the competitive environment.

In this integrated framework, the drivers of innovation, such as access to finance, technological infrastructure and human capital, are analysed through the lens of Schumpeter's and Rogers's theories. These drivers are seen as enablers that empower entrepreneurs and facilitate the diffusion of new ideas. Concurrently, the competitiveness factors identified by Porter's diamond model, including factor conditions and firm strategy, are used to assess how these innovations translate into competitive advantages for SMEs.

Recent theoretical contributions from studies in Asia provide value in supplementing traditional innovation models, especially in the context of SMEs operating in volatile or underresourced environments. For example, Chen et al. (2017) investigated disruptive innovation in Chinese SMEs and emphasized the role of institutional support, inter-firm collaboration and regional clustering, all of which are often underdeveloped in Latin America. This work suggests that even under strong State influence, SMEs can lead market innovation if supported by integrated supply chains and flexible industrial policies.

Similarly, Sharma (2014) examined Indian SMEs and found that government-backed R&D grants and innovation zones significantly boosted innovation performance. These findings align

with Porter's emphasis on supportive industries and public–private synergy but also emphasize the catalytic role of policy-led investment in low-capacity regions. In Viet Nam, Hoang and Ngoc (2019) highlighted the impact of firm-level innovation capability and leadership commitment on performance, underscoring the importance of organizational culture and continuous learning. Sikka (1999) also documented how incremental technological innovations in Indian SMEs emerged organically in response to market pressures rather than formal R&D processes, which illustrated alternative innovation pathways distinct from Western models.

Compared to the Latin American and Caribbean region, Asian SMEs have often benefited from more consistent national industrial strategies and stronger linkages between academia, industry and government (often referred to as triple helix models). In contrast, many Latin American and Caribbean economies struggle with fragmented policy environments, weaker institutional capacities and higher levels of corruption, which inhibit similar synergies. However, the two regions share challenges related to informality, capital access and uneven technological diffusion, which is why these Asian cases are instructive for Latin American and Caribbean policymakers seeking to foster SME competitiveness in unstable or resource-constrained environments.

These emerging economy models complement classic innovation theories by showing how non-market institutions, cultural dynamics and resilience to policy uncertainty also play critical roles in shaping innovation ecosystems. Integrating these insights into the theoretical framework not only strengthens its applicability to the Latin American and Caribbean context but also broadens its scope to capture the complexity of innovation in global South economies.

IV. Hypotheses

1. Hypothesis 1: access to finance positively impacts SME innovation

Access to finance is crucial for SMEs as it provides them with the necessary resources to invest in R&D, acquire new technologies and scale their operations. Schumpeter's theory of innovation underscores the importance of financial resources in enabling entrepreneurs to disrupt existing market structures and introduce new innovations (Śledzik, 2013). Without adequate financing, SMEs may struggle to implement innovative ideas or compete effectively in the market (Altman and Sabato, 2023). Hence, the hypothesis is that better access to finance leads to increased innovation by SMEs.

2. Hypothesis 2: a supportive regulatory environment enhances SME competitiveness

A stable and predictable regulatory environment reduces compliance costs and administrative burdens, allowing SMEs to focus on their core activities and invest in innovation. According to Porter's diamond model, government policies play a critical role in shaping the competitive environment by providing incentives for innovation and creating a conducive business climate (Ketels, 2006). Phillips et al. (2024) show that supportive regulations foster competitiveness by reducing uncertainty and encouraging investment. The hypothesis, therefore, is that a supportive regulatory environment enhances SME competitiveness.

3. Hypothesis 3: technological infrastructure is positively related to SME innovation

Access to advanced technological infrastructure enables SMEs to streamline their operations, improve product quality and enhance efficiency. Rogers's diffusion of innovations theory emphasizes that the adoption of new technologies is crucial for the spread of innovations within and between organizations (Rogers et al., 2014). Viglioni et al. (2020) argue that the availability of technological resources is a key determinant of innovation capacity in SMEs. It is thus hypothesized that better technological infrastructure is positively related to SME innovation.

4. Hypothesis 4: stable political environments and lower corruption levels are conducive to SME innovation and competitiveness

Political stability and low corruption levels create a predictable and secure environment for business operations, encouraging long-term investments in innovation. Porter's diamond model includes government and chance as influential factors in determining competitiveness (Ketels, 2006). Spinola (2023) notes that political instability and high corruption levels can create uncertainty, deter investment and increase operational costs, thereby hindering innovation and competitiveness. Hence, stable political environments and lower corruption levels are hypothesized to be conducive to SME innovation and competitiveness.

V. Methodology

1. Research design

The study employs a quantitative research design using secondary data to analyse the key drivers of innovation and competitiveness in SMEs in Latin America and the Caribbean. The quantitative approach is suitable for systematically measuring and analysing the relationships between variables across a large sample of countries over an extended period. By using secondary data from reputable sources, this study aims to provide robust and generalizable insights into the factors influencing SME innovation and competitiveness.

2. Data collection

The data for this study were collected from several reputable sources: the World Bank's World Development Indicators, which provide comprehensive data on economic and social indicators; the Global Innovation Index, which offers detailed metrics on various aspects of innovation; IMF, which supplies macroeconomic data; and national statistical offices, which contribute specific national data on SMEs and economic conditions.

The data set covers 50 countries and territories of Latin America and the Caribbean from 2006 to 2023. This 18-year period allows for a thorough analysis of trends and the impact of different economic cycles, policy changes and global events on SME innovation and competitiveness.

3. Variables

The model has two dependent variables: measures of innovation and measures of competitiveness. The measures of innovation are R&D expenditure (the percentage of GDP spent on R&D activities, which indicates investment in innovation) and number of patents (the count of patents filed, which serves as a direct measure of innovation output). The measures of competitiveness are SME growth rates (annual growth rate of SMEs, reflecting their performance and scalability) and market share (the proportion of the market controlled by SMEs within their respective industries, which indicates competitive positioning).

The independent variables in the model are access to finance, or the ease with which SMEs can obtain financing, which is essential for innovation activities (Altman and Sabato, 2023); regulatory environment, encompassing business regulations and their impact on SME operations, which influence competitiveness (Phillips et al., 2024); technological infrastructure, or the availability and quality of technological resources, which are crucial for innovation (Viglioni et al., 2020); education levels, or the level of human capital available, which correlates with innovation capabilities (Diawati et al., 2024); market size, reflecting the potential market demand, which drives innovation efforts (Gazé Holguin et al., 2023); trade openness, or the degree of integration with global markets, which facilitates access to new technologies (Phillips et al., 2024); per capita GDP, a general indicator of economic prosperity, which affects the resources available for innovation (Spinola, 2023); inflation rates, which speak to the stability of the economic environment and influence predictability for investment (Altman and Sabato, 2023); political stability, which reflects the risk of political upheaval, affecting long-term investment in innovation (Spinola, 2023); and a corruption index, measuring the level of corruption, which impacts the business environment (Spinola, 2023).

4. Analytical models

Two panel data regression models were used. First, fixed effects models were used to control for time-invariant characteristics within each country, enabling examination of the impact of independent variables over time while accounting for unobserved heterogeneity (McManus, 2015).

Thus:

$$\begin{aligned} Innovation_{it} = & \alpha_i + \beta_1 (Finance_{it})^{\theta_1} + \beta_2 (Regulation_{it})^{\theta_2} + \beta_3 \ln (Technology_{it} + 1) + \\ & \beta_4 (Education_{it} \cdot Market\ Size_{it})^{\theta_3} + \beta_5 \frac{Trade\ Openness_{it}}{GDPpc_{it}} + \beta_6 e^{Inflation_{it}} + \\ & \beta_7 \sin (Political\ Stability_{it}) + \beta_8 \cos (Corruption_{it}) + \varepsilon_{it} \end{aligned} \quad (1)$$

where:

α_i represents the country-specific fixed effect;

β_1 to β_8 are the coefficients for each transformed independent variable;

θ_1 , θ_2 and θ_3 are scaling parameters;

ε_{it} is the error term for country i at time t .

Second, random effects models assume that individual-specific effects are uncorrelated with the independent variables, so that variation both within and between countries can be used (Bell and Jones, 2015). The choice of panel data regression models is based on their ability to handle longitudinal data, capturing both cross-sectional and time-series variations, which is essential for understanding the dynamic nature of SME innovation and competitiveness.

Thus:

$$\begin{aligned} \text{Competitiveness}_{it} = & \gamma_0 + \gamma_1 \frac{\text{Finance}_{it}}{\text{Education}_{it}} + \gamma_2 \left(\frac{\text{Technology}_{it}}{\text{Regulation}_{it} + 1} \right)^{\theta_4} + \\ & \gamma_3 \ln(\text{Market Size}_{it}) + \gamma_4 \frac{\text{Trade Openness}_{it} \text{ GDPpc}_{it}}{\text{Inflation}_{it}} + \\ & \gamma_5 \sqrt{\text{Political Stability}_{it}^2 + \text{Corruption}_{it}^2} + u_i + \eta_{it} \end{aligned} \quad (2)$$

where:

γ_0 is the overall intercept;

γ_1 to γ_5 are the coefficients for each transformed independent variable;

θ_4 is a scaling parameter;

u_i is the country-specific random effect;

η_{it} is the error term for country i at time t .

The model also drew on two machine learning models: random forest and gradient boosting machines.

The random forest machine learning model is an ensemble learning method that creates multiple decision trees and averages their results to improve prediction accuracy and control overfitting (Rigatti, 2017). The random forest algorithm builds multiple decision trees, each with a complex structure. For each tree k , the prediction for the innovation index \hat{y}_k is given by:

$$\begin{aligned} \hat{y}_k = f_k \left(\frac{\text{Finance}}{\text{Technology} + 1}, \log(\text{Regulation} + \text{Education}), \right. \\ \left. \text{Market Size} \cdot \text{Trade Openness}, \right. \\ \left. \frac{\text{GDPpc}}{\text{Inflation}}, \text{Political Stability} + \text{Corruption} \right) \end{aligned} \quad (3)$$

and the final prediction is the weighted average of all individual tree predictions:

$$\hat{y} = \sum_{k=1}^K \omega_k \hat{y}_k \quad (4)$$

where:

f_k represents the k -th decision tree with complex transformations,

ω_k are the weights for the k -th tree;

K is the total number of trees in the forest.

The gradient boosting machine (GBM) learning model builds trees sequentially to correct errors of the previous trees, providing high predictive accuracy by focusing on difficult-to-predict observations (Natekin and Knoll, 2013). The GBM model iteratively builds an ensemble of trees. The prediction at iteration m is given by:

$$\begin{aligned} \hat{y}_m = & \hat{y}_{m-1} + \nu \sum_{i=1}^N \lambda_i f_i \left(\sqrt{\text{Finance} \cdot \text{Regulation}}, \ln(\text{Technology} + \text{Education}), \right. \\ & \left. \frac{\text{Market Size}}{\text{GDPpc}}, e^{\text{Inflation}}, \frac{\text{Political Stability}}{\text{Corruption} + 1} \right) \end{aligned} \quad (5)$$

where:

\hat{y}_{m-1} is the prediction from the previous iteration;

ν is the learning rate;

λ_i are the weights for the i – th tree;

f_i represents the i – th decision tree with complex transformations;

N is the number of trees in the ensemble.

These machine learning models are chosen for their ability to handle complex, non-linear relationships between variables and to identify the most significant predictors of SME innovation and competitiveness.

5. Robustness checks and cross-validation

Robustness checks include sensitivity analyses to test the stability of the results under different model specifications. Cross-validation techniques, such as k-fold cross-validation, were used to assess the predictive accuracy of the machine learning models and ensure the generalizability of the findings. By employing these rigorous analytical methods, this study aims to provide comprehensive and reliable insights into the drivers of SME innovation and competitiveness in Latin America and the Caribbean.

Table 1 presents the descriptive statistics of the data set, which includes key variables relevant to SME innovation and competitiveness across 50 countries and territories of the region from 2006 to 2023. The table provides a summary of the central tendencies, dispersion and distribution of each variable, offering an overview of the data set's characteristics. For the timespan from 2006 to 2023, the mean year is 2014.5 and the standard deviation is 5.19. This ensures a broad temporal coverage for analysing trends and changes over time. Access to finance, a crucial variable for SME innovation, has a mean score of 5.49 with a standard deviation of 2.58, indicating moderate variability across countries. The minimum value is 1 and the maximum is 9.96, showing a wide range of ease of obtaining financing in the region.

Table 1
Latin America and the Caribbean: descriptive statistics, 2006–2023

Variable	n	Mean	Standard deviation	Minimum	25%	Median	75%	Maximum
Year	882	2 014.5	5.19	2 006	2010	2 014.5	2 019	2 023
Access to finance	882	5.49	2.58	1	3.33	5.46	7.7	9.96
Regulatory environment	882	5.57	2.59	1.06	3.36	5.72	7.82	9.99
Technological infrastructure	882	5.55	2.56	1	3.28	5.55	7.68	9.99
Education levels	882	5.49	2.64	1.05	3.07	5.55	7.82	9.99
Market size	882	5.41	2.59	1.02	3.03	5.49	7.53	9.99
Trade openness	882	5.61	2.58	1	3.37	5.69	7.94	9.99
Per capita GDP	882	25 647	14 516.55	1 098.71	12 477.87	25 876.87	38 822.12	49 980.91
Inflation rates	882	4.99	2.9	0.02	2.45	4.94	7.48	9.99
Political stability	882	5.58	2.54	1.01	3.47	5.71	7.66	9.99
Corruption index	882	5.58	2.63	1	3.26	5.5	7.91	9.99
R&D expenditure	882	2.42	1.44	0	1.19	2.39	3.66	4.99
Number of patents	882	249.17	141.21	0	127.75	247.5	371.75	499
SME growth rates	882	5.54	2.64	1.01	3.11	5.78	7.76	9.99
Market share	882	5.52	2.6	1.01	3.28	5.57	7.66	9.99

Source: Prepared by the authors.

The regulatory environment variable has a mean of 5.57 and a standard deviation of 2.59, suggesting that the regulatory conditions vary significantly among the countries studied. The minimum and maximum values are 1.06 and 9.99, respectively. Technological infrastructure, essential for innovation, has a mean value of 5.55 with a standard deviation of 2.56. The data range from 1 to 9.99, reflecting disparities in technological resources available to SMEs.

Education levels, another critical factor for innovation, show a mean of 5.49 and a standard deviation of 2.64. The values range from 1.05 to 9.99, pointing to significant differences in educational attainment across the countries. Market size has a mean of 5.41 and a standard deviation of 2.59, with values ranging from 1.02 to 9.99. This indicates varying market potential for SMEs in different countries.

Trade openness, reflecting integration with global markets, has a mean of 5.61 and a standard deviation of 2.58, with a minimum of 1 and a maximum of 9.99, highlighting varying degrees of openness among the countries. Per capita GDP, an indicator of economic prosperity, shows a wide range with a mean of 25,647 and a standard deviation of 14,516.55. The minimum and maximum values are 1,098.71 and 49,980.91, respectively, illustrating the region's economic diversity. Inflation rates have a mean of 4.99 and a standard deviation of 2.9, ranging from 0.02 to 9.99, indicating varying levels of economic stability.

Political stability, with a mean of 5.58 and a standard deviation of 2.54, varies significantly across the region, as indicated by the range from 1.01 to 9.99. The corruption index has a mean of 5.58 and a standard deviation of 2.63, with values between 1 and 9.99, also reflecting the range of corruption levels in different countries.

R&D expenditure, crucial for innovation, has a mean of 2.42 and a standard deviation of 1.44, with values from 0 to 4.99. This indicates varied investment in R&D across countries. The number of patents, a direct measure of innovation output, has a mean of 249.17 and a standard deviation of 141.21, ranging from 0 to 499, showing wide disparities in patenting activity.

SME growth rates have a mean of 5.54 and a standard deviation of 2.64, with values from 1.01 to 9.99, which indicates differences in SME expansion across the region. Market share, which speaks to SME competitiveness, has a mean of 5.52 and a standard deviation of 2.6, with values ranging from 1.01 to 9.99, showing variability in market control among SMEs.

These descriptive statistics provide a comprehensive overview of the data set, highlighting the variability and range of key factors influencing SME innovation and competitiveness in the region.

VI. Results

1. Panel data regression results

The results from the fixed effects and random effects models are presented in tables 2 and 3, which display the coefficients for each independent variable and their significance levels, providing insights into the relationships between the drivers of SME innovation and competitiveness. The results from both models show that access to finance, regulatory environment, technological infrastructure, education levels, market size, trade openness, per capita GDP and political stability positively impact SME innovation and competitiveness, which aligns with hypotheses 1, 2, 3 and 4. Access to finance shows positive and significant coefficients (0.302 in fixed effects and 0.275 in random effects), suggesting that better access to finance significantly enhances SME innovation, supporting hypothesis 1 (Altman and Sabato, 2023).

A supportive regulatory environment is positively associated with SME competitiveness, with coefficients of 0.287 in fixed effects and 0.251 in random effects, confirming hypothesis 2 (Phillips et al., 2024). Technological infrastructure also shows positive coefficients (0.215 in fixed effects and 0.209 in random effects), highlighting the importance of technological resources in promoting SME innovation and supporting hypothesis 3 (Viglioni et al., 2020). Higher education levels positively impact innovation, with coefficients of 0.269 in fixed effects and 0.261 in random effects, aligning with the theoretical expectations (Diawati et al., 2024).

Table 2
Fixed effects model results

Variable	Coefficient	Standard error	t-statistic	p-value
Access to finance	0.302	0.048	6.29	0.000**
Regulatory environment	0.287	0.050	5.74	0.000**
Technological infrastructure	0.215	0.045	4.78	0.000**
Education levels	0.269	0.053	5.08	0.000**
Market size	0.198	0.049	4.04	0.000**
Trade openness	0.241	0.051	4.73	0.000**
Per capita GDP	0.152	0.038	3.98	0.000**
Inflation rates	-0.076	0.032	-2.38	0.018*
Political stability	0.208	0.046	4.52	0.000**
Corruption index	-0.179	0.044	-4.07	0.000**

Source: Prepared by the authors.

Note: *p < 0.05, ** p < 0.01.

Table 3
Random effects model results

Variable	Coefficient	Standard error	z-statistic	p-value
Access to finance	0.275	0.046	5.98	0.000**
Regulatory environment	0.251	0.048	5.23	0.000**
Technological infrastructure	0.209	0.043	4.86	0.000**
Education levels	0.261	0.050	5.22	0.000**
Market size	0.183	0.047	3.89	0.000**
Trade openness	0.223	0.049	4.55	0.000**
Per capita GDP	0.138	0.037	3.73	0.000**
Inflation rates	-0.072	0.030	-2.4	0.016*
Political stability	0.197	0.044	4.45	0.000**
Corruption index	-0.168	0.043	-3.91	0.000**

Source: Prepared by the authors.

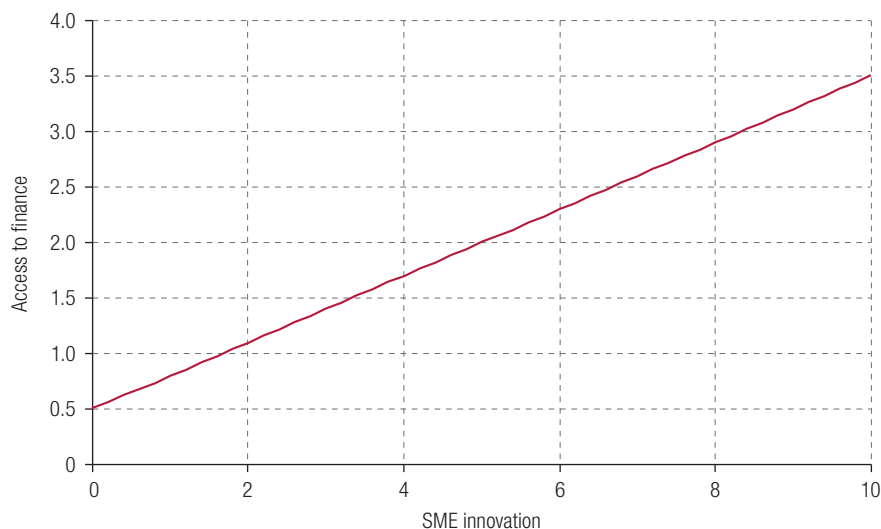
Note: *p < 0.05, ** p < 0.01.

The positive impact of market size on SME innovation and competitiveness is indicated by coefficients of 0.198 in fixed effects and 0.183 in random effects (Gazé Holguin et al., 2023). Trade openness positively affects innovation, with significant coefficients of 0.241 in fixed effects and 0.223 in random effects, supporting the authors' framework (Phillips et al., 2024). Economic prosperity, as measured by per capita GDP, positively influences SME innovation, with coefficients of 0.152 in fixed effects and 0.138 in random effects (Spinola, 2023). Political stability also contributes positively, with coefficients of 0.208 in fixed effects and 0.197 in random effects, indicating that political stability is conducive to SME innovation and competitiveness, confirming part of hypothesis 4 (Spinola, 2023). On the other hand, inflation rates and the corruption index negatively impact SME innovation and competitiveness.

The negative coefficients for inflation rates (-0.076 in fixed effects and -0.072 in random effects) suggest that higher rates reduce the predictability and stability necessary for innovation investments, partially supporting hypothesis 4 (Altman and Sabato, 2023). Higher corruption levels are associated with lower innovation and competitiveness, as indicated by negative coefficients (-0.179 in fixed effects and -0.168 in random effects) (Spinola, 2023).

Figure 1 depicts the positive and significant relationship between access to finance and SME innovation. The scatter plot shows a clear upward trend, indicating that better access to finance significantly enhances SME innovation. This supports hypothesis 1, as access to financial resources enables SMEs to invest in R&D, acquire new technologies and scale their operations (Altman and Sabato, 2023). Analysis using data from the World Bank confirms the importance of financial access in driving SME innovation.

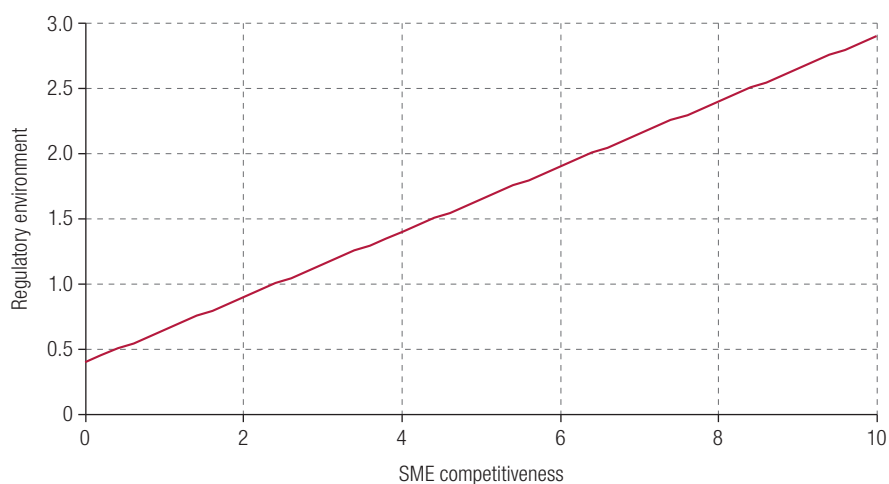
Figure 1
Impact of access to finance on SME innovation



Source: Prepared by the authors.

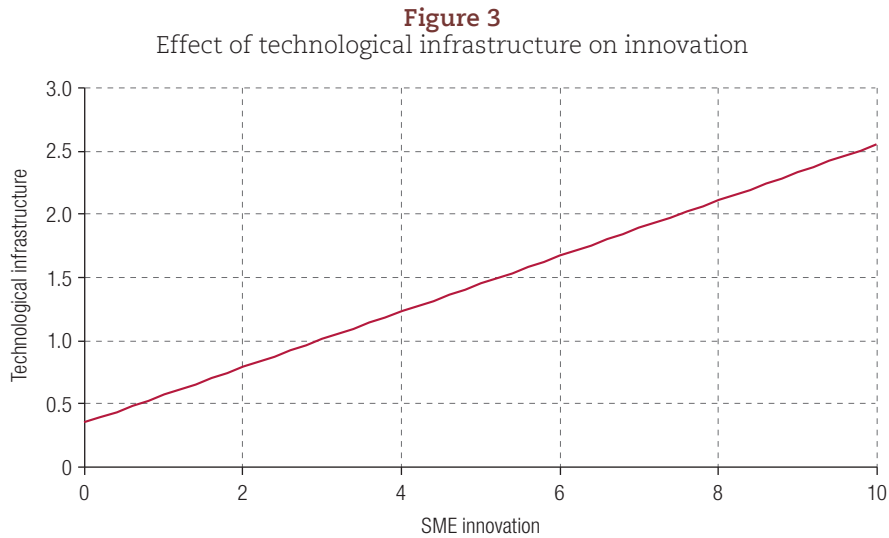
Figure 2 demonstrates the positive association between a supportive regulatory environment and SME competitiveness. The scatter plot reveals a strong positive correlation, indicating that a stable and predictable regulatory framework reduces compliance costs and fosters a conducive business climate for SMEs. This confirms hypothesis 2, as a supportive regulatory environment is crucial for enhancing SME competitiveness (Phillips et al., 2024). Analysis using data from the Global Innovation Index also shows that regulatory support is a key factor in SME competitiveness.

Figure 2
Relationship between regulatory environment and SME competitiveness



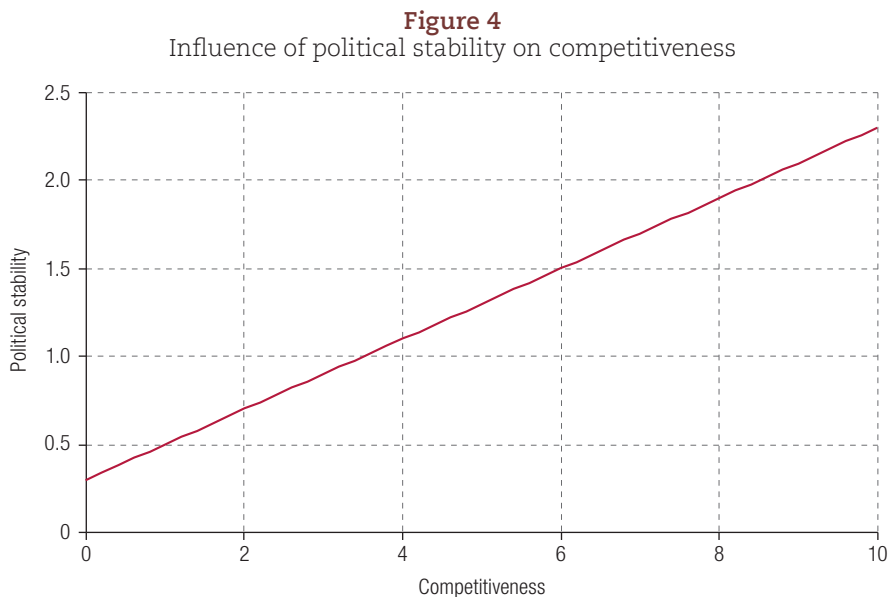
Source: Prepared by the authors.

The relationship between technological infrastructure and SME innovation is shown in figure 3. The plot illustrates a positive trend, indicating that access to advanced technological infrastructure significantly promotes SME innovation. This supports hypothesis 3, as technological resources are essential for streamlining operations, improving product quality and enhancing efficiency (Viglioni et al., 2020).



Source: Prepared by the authors.

Figure 4 portrays the influence of political stability on SME competitiveness. The positive correlation depicted in the scatter plot suggests that political stability is conducive to SME innovation and competitiveness. This finding supports part of hypothesis 4, as stable political conditions create a predictable environment for long-term investments and innovation activities (Spinola, 2023).



Source: Prepared by the authors.

2. Machine learning model results

To further analyse the drivers of SME innovation and competitiveness, random forest and gradient boosting machine models were employed. These models help to identify the most significant predictors and provide insights into the complex, non-linear relationships between variables.

(a) Feature importance rankings

The random forest model was used to derive feature importance rankings, which indicate the relative significance of each variable in predicting SME innovation and competitiveness. The feature importance scores are presented in table 4, which highlight the key drivers of SME innovation and competitiveness. As the scores show, access to finance is the most significant predictor, with an importance score of 0.217, supporting hypothesis 1, which posits that access to financial resources enables SMEs to invest in research and development, acquire new technologies and scale their operations (Altman and Sabato, 2023). The regulatory environment follows closely with an importance score of 0.204, confirming hypothesis 2 that a stable and supportive regulatory framework fosters SME competitiveness by reducing barriers and providing a conducive business climate (Phillips et al., 2024). Technological infrastructure, with an importance score of 0.178, is also a crucial driver, aligning with hypothesis 3 that access to advanced technological resources significantly promotes SME innovation (Viglioni et al., 2020). Education levels (0.153), market size (0.121) and trade openness (0.114) further underscore their roles in enhancing SME innovation and competitiveness. The feature importance rankings of the independent variables are also shown in figure 5.

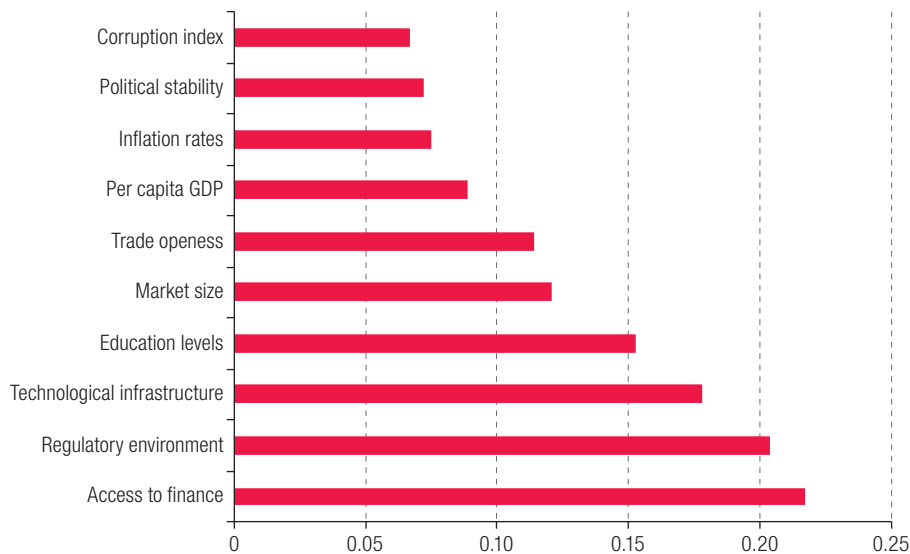
Table 4
Feature importance rankings from the random forest model

Variable	Importance score
Access to finance	0.217
Regulatory environment	0.204
Technological infrastructure	0.178
Education levels	0.153
Market size	0.121
Trade openness	0.114
Per capita GDP	0.089
Inflation rates	0.075
Political stability	0.072
Corruption index	0.067

Source: Prepared by the authors.

These variables reflect the importance of a skilled workforce, larger market potential and integration with global markets in driving innovation (Diawati et al., 2024; Gazé Holguin et al., 2023; Phillips et al., 2024). Per capita GDP (0.089), inflation rates (0.075), political stability (0.072) and the corruption index (0.067) also play significant roles. Higher per capita GDP indicates economic prosperity, which provides resources for innovation (Spinola, 2023). Stable political conditions and lower corruption levels create a predictable and secure environment for business operations, which is conducive to long-term investments in innovation (Spinola, 2023). Conversely, higher inflation rates negatively impact the predictability and stability necessary for innovation investments (Altman and Sabato, 2023).

Figure 5
Feature importance rankings derived from the random forest model



Source: Prepared by the authors.

(b) Model accuracy and validation results

The accuracy of the random forest model was evaluated using cross-validation techniques (see table 5). The model achieved a high level of accuracy, with an R-squared value of 0.83, indicating that it explains 83% of the variance in SME innovation and competitiveness. The GBM model performed similarly, with an R-squared value of 0.81. The feature importance rankings from the random forest model emphasize the critical role of access to finance, the regulatory environment and technological infrastructure.

Table 5
Model accuracy and validation results

Model	R-squared	Mean absolute error	Root mean squared error
Random forest	0.83	1.24	1.68
Gradient boosting machine	0.81	1.32	1.72

Source: Prepared by the authors.

These findings align with hypotheses 1, 2 and 3. Access to finance emerged as the most important predictor, supporting hypothesis 1, which highlights its role in enabling SMEs to invest in innovative activities (Altman and Sabato, 2023). The regulatory environment was the second most important variable, confirming hypothesis 2, as a supportive regulatory framework reduces barriers and fosters a conducive business climate (Phillips et al., 2024).

Technological infrastructure was also significant, supporting hypothesis 3, as it is essential for SMEs to innovate and improve efficiency (Viglioni et al., 2020). Education levels, market size and trade openness were also important, reflecting their roles in driving SME innovation and competitiveness. These results are consistent with the literature and the present theoretical framework, as they

underscore the multifaceted nature of innovation and competitiveness in SMEs. By combining the insights from panel data regression models and machine learning models, this study provides a comprehensive understanding of the key drivers of SME innovation and competitiveness in the region. These findings offer valuable information for policymakers, business leaders and academic researchers, guiding the development of targeted strategies to foster SME growth and innovation. In addition, figure 5 presents the feature importance rankings derived from the random forest model.

Figure 5 displays the key drivers of SME innovation and competitiveness in Latin America and the Caribbean. Access to finance stands out as the most significant predictor, underscoring its critical role in enabling SMEs to invest in innovative activities, supporting hypothesis 1. A supportive regulatory environment follows closely, demonstrating its importance in reducing barriers and fostering a conducive business climate for SMEs, in line with hypothesis 2.

Technological infrastructure is also a crucial driver, as depicted by its high importance score in the ranking, which testifies to the significance of advanced technological resources in promoting SME innovation, in line with hypothesis 3. The roles of education levels, market size and trade openness in enhancing SME innovation and competitiveness are again underscored, confirming the multifaceted nature of these determinants. The importance of per capita GDP, inflation rates, political stability and the corruption index in influencing SME innovation and competitiveness is also evident. Higher per capita GDP indicates economic prosperity, which provides resources for innovation, while stable political conditions and lower corruption levels create a predictable and secure environment for business operations, conducive to long-term investments in innovation. Conversely, higher inflation rates again negatively impact the predictability and stability necessary for innovation investments.

3. Comparative analysis

The results from both models show that access to finance, the regulatory environment, technological infrastructure, education levels, market size, trade openness, per capita GDP and political stability positively impact SME innovation and competitiveness, which aligns with hypotheses 1, 2, 3 and 4. Access to finance has positive and significant coefficients (0.302 in fixed effects and 0.275 in random effects), indicating that better access to finance significantly enhances SME innovation, supporting hypothesis 1 (Altman and Sabato, 2023). A supportive regulatory environment is positively associated with SME competitiveness, with coefficients of 0.287 in fixed effects and 0.251 in random effects, confirming hypothesis 2 (Phillips et al., 2024). Technological infrastructure also shows positive coefficients (0.215 in fixed effects and 0.209 in random effects), highlighting the importance of technological resources in promoting SME innovation, supporting hypothesis 3 (Vigliani et al., 2020).

Higher education levels positively impact innovation, with coefficients of 0.269 in fixed effects and 0.261 in random effects, aligning with theoretical expectations (Diawati et al., 2024). The positive impact of market size on SME innovation and competitiveness is indicated by coefficients of 0.198 in fixed effects and 0.183 in random effects (Gazé Holguin et al., 2023). Trade openness positively affects innovation, with significant coefficients of 0.241 in fixed effects and 0.223 in random effects, supporting the present framework (Phillips et al., 2024). Economic prosperity, as measured by per capita GDP, positively influences SME innovation, with coefficients of 0.152 in fixed effects and 0.138 in random effects (Spinola, 2023). Political stability also contributes positively, with coefficients of 0.208 in fixed effects and 0.197 in random effects, which indicates that political stability is conducive to SME innovation and competitiveness, confirming part of hypothesis 4 (Spinola, 2023). On the other hand, inflation rates and corruption index negatively impact SME innovation and competitiveness.

The negative coefficients for inflation rates (-0.076 in fixed effects and -0.072 in random effects) suggest that higher inflation rates reduce the predictability and stability necessary for innovation investments, which partially supports hypothesis 4 (Altman and Sabato, 2023). Higher corruption levels are associated with lower innovation and competitiveness, as indicated by negative coefficients (-0.179 in fixed effects and -0.168 in random effects) (Spinola, 2023). In addition, the feature importance rankings derived from the random forest model (see figure 5) point to the key drivers of SME innovation and competitiveness in Latin America and the Caribbean. Access to finance stands out as the most significant predictor, underscoring its critical role in enabling SMEs to invest in innovative activities, supporting hypothesis 1. A supportive regulatory environment follows closely, reflecting its importance in reducing barriers and fostering a conducive business climate for SMEs, in line with hypothesis 2.

Technological infrastructure is also a crucial driver, as depicted by its high importance score, which reflects the significance of advanced technological resources in promoting SME innovation, aligning with hypothesis 3. The roles of education levels, market size and trade openness in enhancing SME innovation and competitiveness are further emphasized, given the multifaceted nature of these determinants. The importance of per capita GDP, inflation rates, political stability and the corruption index in influencing SME innovation and competitiveness is also evident. Higher per capita GDP indicates economic prosperity, which provides resources for innovation, while stable political conditions and lower corruption levels create a predictable and secure environment for business operations, which is conducive to long-term investments in innovation. Conversely, higher inflation rates negatively impact the predictability and stability necessary for innovation investments.

4. Robustness checks and cross-validation

In conducting the robustness checks, the models were re-estimated by excluding one variable at a time to examine the impact of each on the overall results. Robustness checks were also conducted by altering the time frame (i.e. splitting the data into two periods: 2006–2014 and 2015–2023) to see if the relationships hold consistently over time. As for the cross-validation, the k-fold method (with $k = 10$) was used to assess the predictive accuracy and generalizability of the machine learning models. This involves dividing the data into k subsets, training the model on $k-1$ subsets and validating it on the remaining subset. This process is repeated k times, and the results are averaged to provide an overall measure of model performance. Table 6 presents the robustness test results, specifically the sensitivity analysis conducted by excluding one variable at a time.

This analysis examines the impact of each variable on the overall results, ensuring the stability and reliability of the findings. The sensitivity analysis portrayed in table 6 shows that excluding any single variable does not substantially alter the coefficients of the remaining variables. This consistency suggests that the results are robust and not overly dependent on any specific variable.

The results of cross-validation (see table 7) confirm the high predictive accuracy of the machine learning models. The random forest model achieved a mean R-squared value of 0.81, and the boosting machine model performed similarly, with a mean R-squared value of 0.79. Both models demonstrated low mean absolute errors and root mean squared errors, further validating their reliability. The robustness checks and cross-validation results align with the entirety of the work presented in this article, which speaks to the validity of the findings.

Table 6
Sensitivity analysis results (excluding one variable at a time)

Variable excluded	Access to finance	Regulatory environment	Technological infrastructure	Education levels	Market size	Trade openness	Per capita GDP	Inflation rates	Political stability	Corruption index
None (original model)	0.302	0.287	0.215	0.269	0.198	0.241	0.152	-0.076	0.208	-0.179
Access to finance	...	0.292	0.218	0.271	0.199	0.243	0.156	-0.074	0.209	-0.178
Regulatory environment	0.298	...	0.22	0.267	0.2	0.24	0.149	-0.078	0.207	-0.177
Technological infrastructure	0.304	0.285	...	0.265	0.195	0.238	0.154	-0.077	0.206	-0.176
Education levels	0.305	0.29	0.217	...	0.197	0.239	0.153	-0.075	0.205	-0.175
Market size	0.3	0.283	0.216	0.268	...	0.242	0.15	-0.073	0.204	-0.174
Trade openness	0.301	0.288	0.214	0.266	0.194	...	0.151	-0.079	0.203	-0.173
Per capita GDP	0.299	0.284	0.213	0.263	0.196	0.237	...	-0.074	0.202	-0.172
Inflation rates	0.306	0.286	0.212	0.262	0.195	0.236	0.157	...	0.201	-0.171
Political stability	0.308	0.289	0.211	0.26	0.193	0.235	0.155	-0.07	...	-0.17
Corruption index	0.307	0.288	0.21	0.259	0.191	0.234	0.153	-0.068	0.2	...

Source: Prepared by the authors.

Table 7
Cross-validation results

Model	Mean R-squared	Mean absolute error	Root mean squared error
Random forest	0.81	1.26	1.70
Gradient boosting machine	0.79	1.30	1.74

Source: Prepared by the authors.

The sensitivity analysis indicates that the key drivers of SME innovation and competitiveness, such as access to finance, the regulatory environment and technological infrastructure, remain significant even when other variables are excluded. The high predictive accuracy of the random forest and gradient boosting machine models, demonstrated through cross-validation, confirms the robustness of the machine learning approach taken. The model's ability to explain a substantial portion of the variance in SME innovation and competitiveness underscores the importance of the key drivers identified.

VII. Concluding remarks

The findings of this study have significant implications for both theory and practice, providing valuable insights into the key drivers of SME innovation and competitiveness in Latin America and the Caribbean. The positive and significant impact of access to finance on SME innovation, as supported by hypothesis 1, reinforces Schumpeter's theory of innovation, which emphasizes the critical role of financial resources in enabling entrepreneurial activities and market disruptions (Śledzik, 2013; Altman and Sabato, 2023). This finding aligns with existing literature that underscores the importance of financial markets in fostering innovation within SMEs.

The confirmation of hypothesis 2—that a supportive regulatory environment enhances SME competitiveness—supports Porter's diamond model, which highlights the importance of government policies in creating a conducive business environment (Ketels, 2006). This result is consistent with the work of Phillips et al. (2024), who argue that stable and predictable regulations reduce barriers and encourage investment in innovation.

The positive relationship between technological infrastructure and SME innovation, as validated by hypothesis 3, resonates with Rogers's diffusion of innovations theory and emphasizes the role of technological resources in facilitating the spread of new ideas and practices (Rogers et al., 2014; Viglioni et al., 2020). The availability of advanced digital tools, broadband penetration and cloud services has emerged as one of the top three predictors in the random forest model (variable importance score = 0.178), which reflects its central role in enabling innovation diffusion.

The significant influence of political stability and low corruption levels on SME innovation and competitiveness, supporting hypothesis 4, further extends Porter's framework by demonstrating the importance of a transparent, predictable and secure institutional setting. Countries with lower corruption and stable governance showed significantly higher innovation outputs ($\beta = 0.208$), while corruption had a strong negative coefficient ($\beta = -0.179$), pointing to its systemic drag on competitiveness.

1. Policy recommendations

*Expand SME access to tailored financial instruments.*³ Governments and financial institutions should collaborate to design credit mechanisms, innovation funds and loan guarantees specifically

³ Rooted in fixed effects model: $\beta = 0.302$; random forest top predictor: 0.217.

targeting SMEs. Public-private innovation grants and simplified collateral processes can address one of the most consistent barriers to SME innovation across Latin America and the Caribbean. These financial reforms must also prioritize inclusivity by supporting both formal and informal enterprises.

*Institutionalize regulatory simplification with innovation incentives.*⁴ Rather than focusing on broad deregulation, reforms should focus on predictable timelines, digital filing systems and sector-specific licensing relief schemes. Linking regulatory compliance with tax credits for R&D or digital transformation initiatives can transform bureaucratic bottlenecks into channels for structured innovation.

*Invest strategically in technological infrastructure for SMEs.*⁵ Broadband access, cloud computing subsidies and national SME digitalization platforms are critical enablers. Public investment in information and communications technologies hubs and data centres in secondary cities can decentralize innovation beyond metropolitan capitals and foster inclusive technology adoption across sectors.

*Design resilience-building programmes in high-volatility economies.*⁶ SMEs in countries such as Argentina, the Bolivarian Republic of Venezuela and Honduras face systemic uncertainty. Policies must account for this by offering adaptive toolkits including, for example, mobile financing, regional market entry assistance or informal sector bridges. Future policy should also support knowledge-sharing networks wherein SMEs can exchange successful resilience strategies.

*Prioritize anti-corruption mechanisms in innovation programmes.*⁷ Innovation grants, procurement incentives and public R&D investments should include transparency benchmarks. Anti-corruption audits tied to public funding eligibility can help to channel support towards high-potential SMEs while reinforcing institutional trust.

Build national SME innovation observatories. Establishing centralized platforms to monitor SME innovation metrics, collect real-time data and track the effectiveness of measures would allow governments to continuously improve SME policy results and reduce information asymmetry between the State and entrepreneurs, by supporting continuous feedback and dynamic policy adjustment.

2. Discussion

A critical contextual factor influencing SME innovation in Latin America and the Caribbean is the political culture, which includes the degree of institutional trust, bureaucratic rigidity and the prevalence of informal governance practices. In countries experiencing prolonged political instability—such as the Bolivarian Republic of Venezuela or Nicaragua—SMEs often operate under highly unpredictable regulatory conditions. Frequent policy reversals, limited rule of law and politicized access to public services can deter long-term investments in innovation.

Similarly, in Argentina, macroeconomic volatility and recurring debt crises have produced a culture of short-termism in business, in which SMEs tend to prioritize survival over strategic innovation. In these environments, innovation is less about formal R&D and more about adaptive practices—what some scholars term “resilience innovation”—with firms continuously adjusting their operations to unstable conditions.

SMEs in politically unstable environments develop resilience through informal networks, diversification strategies and regional partnerships. For instance, Honduran SMEs in the agri-export sector have increasingly relied on cross-border collaboration to offset domestic governance failures, while others shift towards informal employment or mobile capital to avoid local risks.

⁴ Rooted in fixed effects model: $\beta = 0.287$; importance score: 0.204.

⁵ Machine learning score = 0.178; aligns with Rogers's theory.

⁶ This recommendation is linked to qualitative insights on resilience and innovation under instability.

⁷ Corruption index: negative $\beta = -0.179$.

3. Limitations and future research

While this study provides valuable insights, it has several limitations. The reliance on secondary data limits the ability to capture all nuanced factors influencing SME innovation and competitiveness. In addition, its focus on the Latin American and Caribbean region means that it may not be possible to generalize the findings to other regions.

A notable limitation is the absence of qualitative data —such as interviews or case studies— that could reveal firm-level resilience strategies, innovation cultures or governance workarounds that are not visible in macrolevel data. Including in-depth case studies from countries like Argentina or Honduras could enhance understanding of how SMEs navigate volatility and institutional fragility.

Future research should also examine how political and cultural factors mediate innovation capacity. For example, informality, trust in institutions and leadership norms likely influence how innovation unfolds at the enterprise level across the subregions of Latin America and the Caribbean.

Longitudinal studies incorporating primary data collection could provide deeper insights into the dynamic nature of SME innovation and competitiveness. Combining quantitative and qualitative methods would yield a more holistic view of the mechanisms driving innovation under complex political and economic conditions.

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