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Pathways to innovation in Colombian service SMEs: The role of funding, institutions, and intangible investments

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Abstract

PURPOSE: *This study investigates the multidimensional factors associated with innovation outcomes among innovation-active small and medium-sized enterprises (SMEs) in the Colombian service sector, an emerging economy characterized by financial asymmetries and fragmented innovation support and knowledge-transfer frameworks. The objective is to examine how aggregate funding structures, institutional linkages, and innovation-oriented investments relate differentially to the incidence of product innovation (market-oriented) and process innovation (internally oriented). By disentangling these pathways among innovation-active firms, the study provides evidence on how resource configurations shape innovation trajectories in contexts with relatively low technological intensity.* ***METHODOLOGY:*** *The study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) using firm-level microdata from 2,782 innovation-active service-sector SMEs derived from Colombia's VIII Survey of Technological Development and Innovation (EDIT VIII 2020–2021). All constructs are first-order composites, measured formatively with non-redundant binary indicators that capture multidimensional resource configurations. Two independent structural models are estimated to represent distinct innovation pathways: one explaining the incidence of product and service innovations, and another capturing process-related innovations associated with operational and organizational improvements.* ***FINDINGS:*** *The results reveal a clear asymmetry in the patterns of association observed across innovation outcomes. Institutional support shows the strongest association with product innovation ($\beta = 0.416$), indicating that connectivity with the broader innovation ecosystem—universities, public agencies, and international partners—helps compensate for limited internal R&D capacity in SMEs. Conversely, innovation investment, particularly in intangible assets such as software, training, and intellectual property, shows the strongest association with process innovation ($\beta = 0.371$), highlighting the role of internal capability building for operational upgrading. Funding sources show a positive but comparatively modest association in both models ($\beta = 0.07$), suggesting that financial access operates primarily as an enabling condition when effectively translated into innovation investments and institutional collaboration.* ***IMPLICATIONS:*** *These findings highlight the importance of integrated innovation support mechanisms that extend beyond credit provision. For policymakers, strengthening institutional linkages and knowledge-transfer channels appears particularly effective for fostering market-oriented innovations. For firm managers, prioritizing investment in intangible assets and participating in collaborative networks may help mitigate structural resource constraints and enhance innovation outcomes.* ***ORIGINALITY & VALUE:*** *This study contributes to the literature on innovation in emerging economies by providing context-sensitive evidence on differentiated innovation pathways in service-sector SMEs.*

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Methodologically, it demonstrates the usefulness of composite-based modeling for analyzing national innovation survey data with dichotomous indicators and complements the analysis with an Importance–Performance Map Analysis (IPMA).
Keywords: *SME innovation, product innovation, process innovation, innovation ecosystems, institutional support, innovation finance, intangible investment, absorptive capacity, service-sector SMEs, emerging economies*

INTRODUCTION

Innovation in products and processes is widely recognized as a strategic pillar for competitiveness and sustained economic growth, particularly among service-sector firms in emerging economies. In these contexts, innovation supports firm development and market differentiation while contributing to national strategies aimed at technological upgrading and productive diversification (Croitoru, 2012; Glückler & Bathelt, 2017; Gomes et al., 2018; OECD/Eurostat, 2018).

Research on innovation in small and medium-sized enterprises (SMEs) has been grounded in complementary theoretical perspectives. The resource-based view (Barney, 1991) highlights how valuable, rare, and difficult-to-imitate resources—often intangible—can underpin competitive advantage. The dynamic capabilities approach, in turn, emphasizes the firm's ability to sense and seize opportunities and to reconfigure resources in response to environmental change (D. Teece et al., 1997; D. J. Teece, 2007, 2018). Absorptive capacity theory further underscores the importance of recognizing, assimilating, and applying external knowledge as a prerequisite for innovation and learning-based upgrading (Cohen & Levinthal, 1990; Zahra & George, 2002).

At the systemic level, the triple and quadruple helix models conceptualize innovation as the outcome of interactions among academia, industry, government, and civil society, stressing the role of institutional arrangements and knowledge intermediation in shaping national innovation ecosystems (Carayannis & Campbell, 2012; Etzkowitz & Leydesdorff, 2000). Yet, empirical applications of these systemic frameworks in emerging economies remain limited and fragmented. Much of the evidence is still derived from industrialized contexts, which limits external validity when transferred to settings characterized by institutional fragility, asymmetric access to funding, and persistently low levels of R&D investment (Barbosa et al., 2014; Paus et al., 2022; Spanos et al., 2015).

A persistent challenge in this literature lies in articulating how these system-level conditions are operationalized through firm-level metrics. This research addresses this multi-level linkage by conceptualizing the firm as a functional node that internalizes systemic environmental signals into strategic capabilities (Hessels & Terjesen, 2010; Lundvall, 2010). Systemic conditions—such as financial liquidity, knowledge infrastructure, and public policy incentives—are captured via the firm's effective engagement with these external structures (Edquist, 2005). Specifically, funding sources and institutional linkages are treated not merely as isolated variables, but as proxies for the firm's integration within the National Innovation System (NIS) (Nelson, 1993; Radicic et al., 2016). By quantifying these interactions using firm-level microdata, the study translates macro-environmental pressures into direct correlates of innovation behavior, thereby strengthening the theoretical coherence between the institutional framework and the empirical strategy.

Recent scholarship, therefore, calls for innovation models that are more explicitly contextualized to the structural conditions of developing countries. Common constraints include weak coordination among innovation actors, limited investment in intangible assets, and restricted access to external financing (Asheim & Gertler, 2009; Carvache-Franco et al., 2022; Paus et al., 2022). These contributions converge on a core premise: innovation does not unfold in an institutional vacuum but is embedded in country-specific environments shaped by macroeconomic disparities, institutional fragmentation, and underinvestment in science and technology. Consequently, direct application of frameworks developed in advanced economies may obscure the mechanisms through which firms innovate in less developed contexts. Although prior studies have examined internal capabilities and external linkages as moderators or enablers of innovation, a salient gap persists regarding the joint role of financing conditions, institutional linkages, and innovation-related investment in shaping product and process innovation—particularly in service activities, where innovation is frequently intangible-intensive and operationally oriented (Le & Ha, 2024; Stanko et al., 2015).

To address this empirical and methodological gap, this study estimates two Partial Least Squares Structural Equation Models (PLS-SEM) to examine the relationships between three explanatory composites—Funding Sources (FS), Institutional Support (IS), and Innovation Investment (II)—and two innovation outcomes: Product Innovation (PrI) and Process Innovation (PsI). All constructs are specified as first-order composites and operationalized using non-redundant binary indicators derived from the 2020–2021 Technological Development and Innovation Survey (EDITS VIII), conducted by Colombia's National Administrative Department of Statistics (DANE). Importantly, the analytical sample is restricted to

service-sector firms that report innovation activity; accordingly, the findings should be interpreted as evidence on the factors associated with the incidence of innovation outcomes, conditional on firms being innovation-active.

PLS-SEM is suitable for this setting because the model is composite-based and uses binary indicators that may depart from normality. The approach enables simultaneous estimation of measurement and structural components and supports inference through resampling procedures. Consistent with best practice for composite models, the empirical assessment emphasizes diagnostics aligned with formative specifications—such as indicator collinearity and bootstrapped relevance—and reports bootstrapped uncertainty for structural paths, complemented by predictive-oriented evaluation (Hair et al., 2021).

Conceptually, the study distinguishes two innovation pathways to avoid conflating outcomes that differ in nature and resource requirements. The first model treats product innovation (PrI) as a market-facing outcome plausibly more dependent on ecosystem connectivity, access to external knowledge, and institutional intermediation. The second model treats process innovation (PsI) as an internally configured outcome more closely associated with capability building and organizational upgrading through tangible and intangible investments. This dual-model strategy contributes to the debate on innovation in emerging economies by (i) disaggregating innovation into product and process domains to reveal differentiated patterns of association, (ii) providing context-sensitive evidence for the service sector, and (iii) clarifying that financing channels may be necessary but not sufficient, insofar as their contribution depends on complementarity with institutional connectivity and strategic investment in innovation-related capabilities.

The study makes three contributions. First, it empirically validates a multidimensional conceptual model tailored to innovative service-sector SMEs in an emerging economy. Second, it clarifies how aggregate financing conditions, institutional linkages, and innovation-oriented investment relate to product and process innovation outcomes, highlighting differences in their relative importance across innovation types. Third, it offers policy- and practice-relevant implications for strengthening institutional connectivity and investment capacity in contexts where firm innovation is constrained by asymmetric access to resources and fragmented support infrastructures.

Consistent with the dual-model strategy, the results reveal a differentiated pattern across innovation outcomes. Institutional Support (IS) shows the strongest association with Product Innovation (PrI), suggesting that ecosystem connectivity and intermediation by public and academic actors are particularly salient for market-facing innovation among Colombian service SMEs. In contrast, Innovation Investment (II)—especially intangible-oriented investment—shows the strongest association with Process Innovation (PsI), underscoring the role of internal capability building and organizational upgrading in operational improvements. Funding Sources (FS) are positively associated with both outcomes but exhibit comparatively weaker effects, indicating that financial access alone is insufficient unless complemented by institutional linkages and strategic investment in innovation capabilities.

The rest of the paper is organized as follows: Section 2 reviews the theoretical background and develops the research hypotheses. Section 3 describes the EDITS VIII data, the operationalization of constructs, and the PLS-SEM estimation strategy, including the rationale for estimating separate models for product and process innovation. Section 4 presents the empirical results and model diagnostics. Section 5 discusses the findings in light of the literature and the Colombian service-sector context. Section 6 concludes by presenting implications for policy and management, limitations, and directions for future research.

LITERATURE REVIEW

Theoretical approaches to innovation

Innovation has long been conceptualized as a dynamic and systemic process through which firms generate value by introducing new or significantly improved products, processes, organizational methods, or marketing techniques (Freeman & Soete, 1997; OECD/Eurostat, 2018; Schumpeter, 1935). This systemic perspective of innovation as a multidimensional phenomenon has been reinforced by contributions from various theoretical frameworks that underscore its complexity, interdependence, and contextual nature (Dzikowski, 2022; Godin, 2006).

Among these, the Triple Helix model (Etzkowitz & Leydesdorff, 2000) emphasizes the synergistic interaction between universities, industry, and government in fostering innovation, while the Quadruple Helix extends this perspective by incorporating civil society as a co-creator of knowledge and legitimacy (Carayannis & Campbell, 2012; Galvão et al., 2017). In recent developments, the Quintuple Helix model has been considered in relation to environmental concerns, thereby aligning innovation with the imperatives of ecological sustainability and green transformation (Machado et al., 2024).

The open innovation paradigm, introduced by Chesbrough (2003), challenges the conventional firm boundary by advocating the strategic utilization of external knowledge sources to complement internal capabilities. The hypothesis posits that firms can accelerate innovation processes, reduce costs, and increase flexibility through inbound flows of ideas from research institutions, customers, competitors, and suppliers (Caloghirou et al., 2021; Wang et al., 2020). The outbound dimension further suggests that unused internal knowledge can be externally commercialized to create value (Dahlander & Gann, 2010).

In addition, the dynamic capabilities framework posits that sustained competitive advantage arises from the ability of companies to integrate, build, and reconfigure internal and external resources to address rapidly changing environments (Teece et al., 1997; Teece, 2007, 2018). Innovation is contingent not only on access to novel technologies but also on the capacity to adapt and reconfigure organizational routines and capabilities continuously (Alves et al., 2017; Grant, 1991; Peteraf, 1993).

According to the resource-based view (RBV), innovation emerges from the deployment of valuable, rare, inimitable, and non-substitutable resources, including knowledge assets, skilled human capital, and institutional linkages (Barney, 1991; Grant, 1991; Caloghirou et al., 2021). These capabilities often interact with institutional factors such as public policy and financial support, especially in low- and middle-income economies (Crowley, 2017; Machado et al., 2024). For instance, Xicang et al. (2024) demonstrate that in high-tech firms operating in emerging economies, internal organizational routines and skills are decisive for translating external support into effective innovation outcomes. This reinforces the idea that innovation capacity rests not only on access to resources, but also on the firm's ability to convert them into value through strategic and organizational capabilities.

The absorptive capacity theory further contributes to the extant literature by conceptualizing the ability of companies to identify, assimilate, transform, and exploit external knowledge as a crucial antecedent to innovation (Cohen & Levinthal, 1990; Zahra & George, 2002). Empirical research has confirmed the strong association between absorptive capacity and enhanced innovation outcomes, particularly when firms engage in cooperation with external actors such as universities, governments, and industry associations (Dimos et al., 2024; Moura et al., 2020; Vo et al., 2024).

In Latin America, and particularly in Colombia, innovation capacity is often constrained by institutional weaknesses, underinvestment in research and development (R&D), and limited access to external finance (Acevedo & Diaz-Molina, 2021; Del Carpio-Gallegos & Miralles, 2019; Gómez & Robledo, 2011). In such contexts, firms tend to rely more on internal financing, a practice that, according to Brown et al. (2009), limits their capacity to engage in high-risk innovation. Consequently, the nexus among internal capabilities, institutional support, and external financing is particularly significant in fostering innovation performance.

Taken together, these theoretical perspectives: dynamic capabilities, the resource-based view (RBV), absorptive capacity, and systemic innovation models, provide a comprehensive analytical lens for examining the structural conditions and resource configurations associated with innovation in firms operating in contexts of intermediate technological development and institutional asymmetry, such as those observed in Colombia and other emerging economies.

Key factors associated with innovation in emerging economies

Funding sources

Access to funding is a crucial factor in fostering innovation, particularly for small and medium-sized enterprises (SMEs). Hall and Lerner's (2010) seminal study demonstrated that the availability of financial resources exerts a substantial influence on innovation development, with different funding sources yielding disparate effects. Venture capital, for instance, is often associated with the emergence of disruptive innovations, while bank credit typically supports incremental improvements (Brown et al., 2013). In emerging economies, self-financing remains the predominant funding mechanism for most firms despite its limitations in sustaining long-term innovative activities (Aiello et al., 2020; Kwak, 2021).

The relationship between financing and innovation is far from homogeneous. It varies according to firm size, R&D intensity, and the availability of public and private resources (Littunen et al., 2021). External funding sources, such as venture capital and government grants, tend to encourage riskier, more radical innovations. In contrast, bank loans and internal resources are more likely to support incremental product improvements and process optimization (Calabrese et al., 2024).

In resource-constrained contexts, funding diversification becomes a strategic imperative. Firms that combine public programs, private capital, and alternative mechanisms like equity crowdfunding can broaden their innovation capacity (Aiello et al., 2020; Eldridge et al., 2021; Panitkulpong et al., 2024). Moreover, foreign direct investment and venture capital not only provide liquidity but also foster knowledge transfer, technology assimilation, and the enhancement of organizational capabilities (Bakhouche, 2022; Guadalupe et al., 2012).

Nevertheless, the effectiveness of funding strategies depends on firms' internal capacities to manage financial and technological risk. Empirical research on capital structure suggests that misaligned funding choices may hinder innovation, especially in firms with limited absorptive or managerial capabilities (Martinez et al., 2019). In emerging markets, where information asymmetries and institutional weaknesses are pervasive, these challenges are exacerbated. This reinforces the need for targeted public funding schemes to complement private investments and mitigate systemic gaps (Mardones & Zapata, 2018; Mateut, 2018).

Conceptually, it is important to distinguish between private banking finance and private non-banking finance, as they involve different instruments and governance mechanisms. Bank credit reflects a debt-based relationship between the firm and a financial intermediary, typically shaped by collateral requirements, screening, and repayment capacity. By contrast, private non-banking finance encompasses resources provided by non-bank private agents—such as private investors or firms—and may involve equity or quasi-equity positions, strategic involvement, and complementary networks. This distinction matters for innovation because the bank–firm relationship tends to support projects with more predictable cash flows, whereas non-banking private finance may better accommodate uncertainty and provide "patient" or strategic capital for innovation-oriented activities.

In the Colombian context, the financing environment for innovation is characterized by a marked reliance on internal resources and persistent frictions in accessing external funding. Evidence reported from the national innovation surveys indicates that, among firms attempting to innovate, the scarcity of internal funds and the difficulty of obtaining external finance are recurrently identified as the most binding constraints, while the observed financing mix follows a clear hierarchy in which own resources dominate, followed by private bank credit, whereas public funds, private equity-type instruments, and cooperation/donations play a comparatively marginal role (Gálvez-Albarracín et al., 2018). Sector-focused evidence for Colombian service and commerce firms is consistent with this pattern: internal resources are the primary source for innovation activities, banking funds are mainly allocated to process innovations, and the use of public credit/co-financing remains minimal, in part due to administrative and informational barriers that hinder access to these instruments (Restrepo-Ramírez et al., 2022). This configuration suggests that internal funding in Colombian SMEs often reflects a structural constraint rather than a purely strategic choice, underscoring the need to distinguish between private banking finance (debt-based) and private non-banking finance (equity/quasi-equity and relational capital) when conceptualizing the composite Funding Sources (FS). Complementarily, cross-industry evidence suggests that financing constraints are correlated with the allocation of direct public support in several Colombian industries, underscoring the policy relevance of public instruments as potential mechanisms to relax market failures affecting innovation finance (Busom & Vélez-Ospina, 2017).

In this study, the construct Funding Sources (FS) reflects this multidimensional perspective and is operationalized using four binary indicators from the EDITS VIII survey: internal funding, private banking finance (bank credit), private non-banking finance (private capital), and cooperation or donations. Because these indicators jointly define the composite, the estimated structural coefficient captures the aggregate association of the financing structure with innovation outcomes, rather than the isolated effect of each specific source. Accordingly, the following hypotheses are proposed:

H1a: Funding Sources (FS), considered as an aggregated financing structure, are positively associated with product innovation outcomes in innovative service-sector SMEs.

H1b: Funding Sources (FS), considered as an aggregated financing structure, are positively associated with process innovation outcomes in innovative service-sector SMEs.

Institutional support and cooperation

Support institutions play a fundamental role in enabling innovation by acting as catalysts for knowledge transfer, facilitators of collaboration, and providers of complementary resources that help firms overcome structural barriers. A growing body

of research underscores the importance of universities, research centers, public agencies, and innovation intermediaries in building technological capabilities and diffusing knowledge (Feldman, 2016; Kafetzopoulos et al., 2021; Le & Ha, 2024).

Within the Triple Helix framework, collaboration among academia, industry, and government is regarded as essential for fostering integrated innovation systems (Etzkowitz & Leydesdorff, 2000; Ranga & Etzkowitz, 2013). These interactions are particularly significant in emerging economies, where market failures and institutional deficiencies hinder firms' innovation efforts (Inzelt, 2015; Mêgnigbêto, 2015). Empirical studies show that collaboration with academic and public institutions enhances absorptive capacity, facilitating more complex and sustainable innovation (Hervás-Oliver et al., 2018; Xia & Jia, 2023).

In Colombia, the institutional architecture that supports innovation has evolved since the early 1990s through policy efforts to activate the Sistema Nacional de Innovación (SNI) and strengthen the broader *Sistema Nacional de Ciencia, Tecnología e Innovación* (SNCTI). This institutional arrangement has sought to create an enabling environment for technological development in the productive sector, to connect firms with the scientific system, and to deploy instruments that support and finance I+D+i activities (Velez Agudelo, 2021). Policy implementation has historically relied on public entities such as *COLCIENCIAS* (Administrative Department of Science, Technology and Innovation; currently *Ministerio de Ciencia, Tecnología e Innovación*—MinCiencias) and SME-oriented programs, including *FOMIPYME* (*Fondo Colombiano de Modernización y Desarrollo Tecnológico de las Micro, Pequeñas y Medianas Empresas*), which have framed initiatives for innovation and technology transfer among Colombian SMEs (Villamizar, 2005). In parallel, regional articulation mechanisms—particularly the *Comités Universidad–Empresa–Estado* (CUEE) and the *Alianza Universidad–Empresa–Estado de Bogotá-Región*—have promoted collaborative dynamics through activities such as mapping university research capacities, identifying sectoral innovation needs, and strengthening managerial and intellectual property capabilities, thereby operationalizing knowledge transfer across actors (Ramírez Salazar & García Valderrama, 2010). Nevertheless, qualitative assessments warn that, despite the proliferation of governmental initiatives, instruments are frequently designed in generic terms and remain difficult to access for SMEs, while weak coordination among actors persists—reinforcing the analytical relevance of institutional linkages as a critical but uneven driver of innovation outcomes in the Colombian context (Briceño Marín & Morales Rubiano, 2017).

The expansion into Quadruple and Quintuple Helix models introduces civil society and environmental concerns as additional drivers of inclusive innovation (Carayannis & Campbell, 2012; Mineiro et al., 2021). Within this broader paradigm, technology parks, incubators, and public-private platforms function as coordination nodes that support joint knowledge creation and capability development (Rantala et al., 2021).

From a strategic perspective, cooperative R&D initiatives serve as effective mechanisms to enhance innovation returns by allowing firms to share risks, reduce costs, and access complementary resources (Najib et al., 2021; Ramsza & Karbowski, 2020). These arrangements are particularly relevant in knowledge-intensive sectors, where firm–university–government alliances foster innovation in both products and processes (Luengo-Valderrey, 2018).

However, the outcomes of institutional support vary across contexts. Studies by Dimos et al. (2024) and Trang (2024) caution that the mere availability of resources does not guarantee innovation success, particularly for SMEs with low absorptive capacity or limited managerial competencies. Inappropriately designed programs may even create dependency or opportunistic behavior (Dimos & Pugh, 2016).

Recent evidence highlights the growing relevance of institutional support for process innovation through initiatives such as digital transformation programs, technology transfer services, and knowledge management platforms (Cho & Lee, 2024; Le & Ha, 2024). These environments facilitate tacit knowledge exchange and foster durable innovation networks (Inzelt, 2015; Mineiro et al., 2021).

In this study, the construct Institutional Support (IS) is operationalized using five binary indicators from the EDITS VIII survey, capturing support from public agencies, academic or research institutions, private partners, international organizations, and training entities. As with FS, the estimated coefficient reflects the aggregate association of institutional linkages with innovation outcomes. The following hypotheses are derived from the reviewed literature:

H2a: Institutional Support (IS), understood as an aggregated set of linkages with public, academic, private, international, and intermediary organizations, is positively associated with product innovation outcomes in innovative service-sector SMEs.

H2b: Institutional Support (IS), understood as an aggregated set of linkages with public, academic, private, international, and intermediary organizations, is positively associated with process innovation outcomes in innovative service-sector SMEs.

R&D investment

Investment in research and development (R&D) is a foundational pillar for building technological capabilities and fostering firm-level innovation. A robust body of evidence confirms the positive association between R&D intensity and the emergence of new products, enhanced processes, and productivity gains (Kasych et al., 2021). However, this relationship is influenced by contextual, financial, and organizational conditions.

Among SMEs, financial constraints are a major impediment to R&D investment. Barriers include limited collateral, high uncertainty, and the lack of instruments tailored to innovation finance (Barona-Zuluaga & Rivera-Godoy, 2017; Ferraro et al., 2011). The intangible nature of many R&D outputs heightens risk perceptions, rendering debt-based financing less accessible (Hall & Lerner, 2010).

Public investment emerges as a key lever to counterbalance these barriers. Through subsidies, tax incentives, and co-financing schemes, governments can reduce opportunity costs and stimulate innovation, particularly in strategic sectors (Brautzsch et al., 2015; Liu & Guo, 2024). However, in Latin America, these mechanisms often face design and implementation challenges (Barona-Zuluaga & Rivera-Godoy, 2017; Guarín & García-Estévez, 2021).

The relationship between R&D, innovation, and productivity is increasingly understood as systemic and dynamic. The CDM model (Crépon et al., 1998) and its extensions conceptualize innovation as part of a cumulative process shaped by feedback between performance and investment (Bong & Park, 2021). Successful R&D depends not only on financial input but also on organizational learning and strategic alignment (Guarín & García-Estévez, 2021).

Firm-level factors, such as human capital, governance, and strategy, further shape R&D outcomes. Firms with skilled personnel, absorptive capacity, and explicit innovation goals tend to extract higher returns from R&D (Indrawati et al., 2020; Kasych et al., 2021).

In Colombia, most innovation expenditures are allocated to equipment acquisition, while internal R&D remains a minor share of total investment (Barona-Zuluaga & Rivera-Godoy, 2017; Hurtado & Guzmán, 2014). This pattern reflects a technology adoption model rather than a strategy focused on knowledge creation, potentially limiting the transformative potential of innovation.

In this study, the construct Innovation Investment (II) comprises both tangible and intangible innovation expenditures, operationalized through two binary indicators from the EDITS VIII survey: investment in physical assets (tangible) and investment in R&D, training, software, and intellectual property (intangible). This distinction allows us to assess the individual and combined effects of both investment types on firm-level innovation. Accordingly, the following hypotheses are proposed:

H3a: Innovation Investment (II), capturing tangible and intangible innovation-related investment, is positively associated with product innovation outcomes.

H3b: Innovation Investment (II), capturing tangible and intangible innovation-related investment, is positively associated with process innovation outcomes.

Conceptual model

As a synthesis of the previous hypotheses, the conceptual model of this study is presented in Figure 1. Given that product and process innovation are estimated as separate endogenous constructs, each hypothesis is specified in two parallel forms, one for product innovation and one for process innovation.

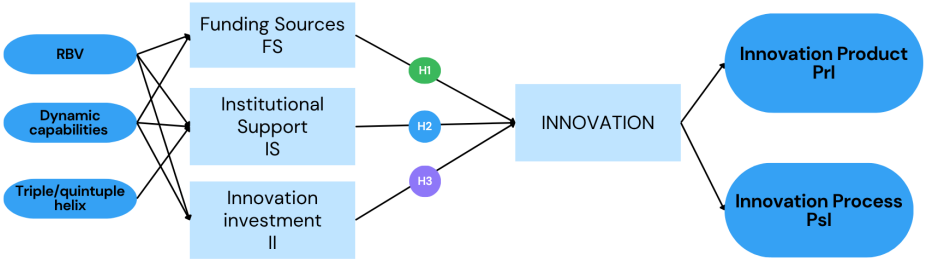

Figure 1. Conceptual model linking funding structures, institutional support, and innovation investment to product and process innovation in service-sector SMEs

The conceptual model integrates three complementary theoretical perspectives—the resource-based view (RBV), dynamic capabilities theory, and the Triple/Quadruple Helix frameworks—to explain how organizational and contextual factors are associated with innovation outcomes in service-sector SMEs operating in an emerging economy. As illustrated in Figure 1, the model links these theoretical foundations to three composite constructs—Funding Sources (FS), Institutional Support (IS), and Innovation Investment (II)—which represent aggregated resource configurations shaping firms' innovation performance.

From the perspective of the resource-based view, firms achieve competitive advantages when they possess valuable, rare, and strategically deployable resources (Barney, 1991; Grant, 1991). In this framework, financial capacity, knowledge access, and organizational investment are critical inputs that enable innovation activities. Accordingly, the constructs FS, IS, and II are conceptualized as complementary resource domains capturing firms' access to financing mechanisms, external knowledge and institutional linkages, and investments oriented toward innovation capabilities.

Dynamic capabilities theory extends this resource-based logic by emphasizing the firm's ability to integrate, reconfigure, and renew its resource base in response to changing environments (Teece et al., 1997; Teece, 2007, 2018). This perspective is particularly relevant for Innovation Investment (II), which encompasses both tangible and intangible investments supporting learning, capability upgrading, and internal transformation. Institutional Support (IS) also reflects dynamic capability processes, as external relationships facilitate knowledge recombination, access to complementary resources, and adaptive responses to technological and market changes.

The Triple and Quadruple Helix frameworks add a systemic dimension by highlighting the role of interactions among universities, government, industry, and civil society in shaping innovation ecosystems (Etzkowitz & Leydesdorff, 2000; Carayannis & Campbell, 2012). These interactions are especially captured through the Institutional Support construct, which reflects firms' engagement with public agencies, research institutions, private organizations, and innovation intermediaries that facilitate knowledge diffusion and collaborative learning.

Building on these theoretical perspectives, the model proposes three sets of direct relationships between the composite constructs and firms' innovation outcomes. Hypotheses H1a and H1b propose that Funding Sources (FS), representing an aggregated financing structure combining internal, public, private, and cooperative funding channels, are positively associated with product innovation (PrI) and process innovation (PsI), respectively. Hypotheses H2a and H2b posit that Institutional Support (IS), capturing firms' external linkages with public institutions, academic actors, private partners, international organizations, and innovation intermediaries, is positively associated with product and process innovation outcomes. Finally, Hypotheses H3a and H3b propose that Innovation Investment (II), reflecting tangible and intangible investments oriented toward innovation activities, is positively associated with both types of innovation outcomes.

These relationships are tested using two separate PLS-SEM models, with product innovation (PrI) and process innovation (PsI) specified as endogenous constructs. Distinguishing between these two outcomes is theoretically and empirically relevant, as product innovation tends to be more market-oriented and influenced by external ecosystem interactions, whereas process innovation is often more closely related to internal capability development and resource reconfiguration. Estimating separate models, therefore, allows a clearer assessment of how aggregated resource configurations influence distinct innovation pathways in service-sector SMEs.

METHODOLOGY

Measures and instrument development

This study utilizes firm-level microdata from the VIII Technological Development and Innovation Survey (EDIT VIII 2020–2021), conducted by Colombia's National Administrative Department of Statistics (DANE). Although the reference period (2020–2021) precedes the current year, EDIT VIII represents the most recent comprehensive dataset available for the Colombian service sector. In emerging economies, national innovation surveys often face structural lags due to the complexity of multi-stage data collection, institutional validation, and public release; as a result, these data remain the empirical frontier for analyzing innovation dynamics in this context.

To ensure methodological rigor, all constructs were operationalized as first-order composites (formative measurement). The use of dichotomous variables (0 = No; 1 = Yes) aligns with the survey's structure and the Oslo Manual guidelines (OECD/Eurostat, 2018). This binary format is also compatible with composite-based structural equation modeling, which does not require distributional normality assumptions (Hair et al., 2021).

The analytical sample was restricted to innovative service-sector firms (TIPOLO ≠ "NOINNO"), yielding 2,782 observations. This restriction creates a conditional scope for interpretation: the estimated relationships represent correlates of innovation incidence among firms already engaged in innovation activities, rather than explanations of the transition from non-innovator to innovator status. This conditioning is practically necessary because several key indicators—such as innovation funding and institutional support—are structurally unavailable in the survey for firms that report no innovation activity. Consequently, the results characterize the pathways associated with innovation outcomes among firms already embedded in the innovation ecosystem.

To document the empirical distribution of novelty levels in the original EDITS VIII indicators, we examined the prevalence of product innovations new to the firm, the national market, and the international market prior to constructing the final Product Innovation (PrI) composite. The results reported in Appendix 4 show that firm-level novelty is substantially more frequent (21.5% for new goods and 15.2% for improved goods), whereas novelty at the national market level is uncommon (1.37% and 1.08%, respectively) and novelty at the international market level is extremely rare (0.11% and 0.07%, respectively). This distribution confirms that higher novelty categories exhibit very limited variance in the sample. Accordingly, national and international novelty indicators were aggregated into broader market-novelty variables in order to preserve the conceptual distinction between firm-level and market-level novelty while ensuring sufficient variability for stable model estimation.

The model includes two dependent constructs that represent distinct innovation outcomes:

- Product Innovation (PrI): Measured through four indicators capturing the introduction of new or significantly improved goods/services (new_goods_firm, improved_goods_firm, new_goods_market, improved_goods_market). Market novelty indicators aggregate national and international levels;
- Process Innovation (PsI): Captures internal operational improvements through six indicators: *production, organization, marketing, distribution, information systems,* and *accounting methods*.

These innovation outcomes are explained by three independent, multidimensional constructs:

- Funding Sources (FS): A composite of four indicators (*internal, banks, private, donations*) reflecting the firm's financing configuration (Czarnitzki, 2006; Sohn et al., 2007);
- Institutional Support (IS): Captures linkages with five external pillars: *public, academic, private, international,* and *training* entities. This aligns with Triple and Quadruple Helix frameworks (Etzkowitz & Leydesdorff, 2000; Carayannis & Campbell, 2012);
- Innovation Investment (II): Distinguishes between *tangible* (physical capital) and *intangible* investment (R&D, software, IP, training), allowing for an assessment of knowledge-based vs. structural modernization (Liu & Guo, 2024).

Each construct consists of non-overlapping, theory-informed indicators. As detailed in Appendix 1, these indicators represent distinct yet complementary aspects of firm-level dynamics, reinforcing the formative nature of the measurement model. To ensure the adequacy of the composite measurement specification, the measurement model was evaluated using criteria appropriate for formative (composite) constructs. Variance Inflation Factors (VIF) were computed to assess potential multicollinearity among indicators, using a conservative threshold of 3.3. Bootstrapping with 5,000 replications was used to obtain sampling-based uncertainty estimates for composite weights and structural paths (Hair et al., 2021). Given the composite (formative) specification, traditional reflective reliability and validity metrics (e.g., Cronbach's alpha, composite reliability, AVE, Fornell–Larcker) are not used as decision criteria for measurement quality in this study.

Data collection

The empirical analysis draws on firm-level microdata from the Eighth Technological Development and Innovation Survey (EDIT VIII) conducted by Colombia's National Administrative Department of Statistics (DANE) for the 2020–2021 period. As previously noted, EDIT VIII represents the most recent comprehensive firm-level evidence available for the Colombian service sector. The survey provides detailed information on innovation-related inputs—including financing channels, institutional support, and strategic investments—making it particularly suitable for examining innovation dynamics in an emerging-economy context characterized by structural asymmetries and fragmented support infrastructures.

To ensure analytical precision and maintain consistency between the systemic innovation framework and firm-level empirical indicators, the original dataset of 8,812 firms was refined through a sequential filtering strategy.

First, firms classified as "non-innovators" were excluded using the survey's typology variable (TIPOLO = "NOINNO"). This step yields an analytical sample of firms that report active engagement in innovation activities. Consequently, the estimated models are not intended to explain the transition into innovation activity; rather, they are specified to examine the correlates of product and process innovation incidence among firms that have already crossed the threshold of innovation engagement. This conditioning is methodologically necessary because several key indicators—particularly those related to innovation funding and institutional support—are structurally unavailable in the survey for firms that do not report innovation activity.

Second, the analysis was restricted to the service sector, as defined by the International Standard Industrial Classification (ISIC Rev. 4). This focus enhances comparability, acknowledging that innovation patterns and capability requirements in services differ fundamentally from those in manufacturing (Stanko et al., 2015). The final analytical sample consists of 2,782 innovative service-sector firms with valid responses across all indicators. This sample size comfortably exceeds the recommended minimum requirements for Partial Least Squares Structural Equation Modeling (PLS-SEM), even under composite-based specifications with multiple binary indicators (Hair et al., 2021).

Third, following the official SME classification established by Colombian regulations (Law 590 of 2000; Law 905 of 2004) and consistent with previous empirical applications using EDIT microdata (Romero-Alvarez et al., 2025), the sample was explicitly restricted to small and medium-sized enterprises (SMEs). In line with the criteria set by Colombia's Ministry of Commerce, Industry, and Tourism, firms were categorized by total number of employees. Specifically, the sample includes only small firms (between 11 and 50 employees) and medium-sized firms (between 51 and 200 employees). Large firms (exceeding 200 employees) and micro-enterprises (fewer than 10 employees) were excluded to ensure the theoretical framework's focus on resource constraints and financial asymmetries remains internally valid.

Following these three sequential filters—(i) innovation activity, (ii) service sector, and (iii) size constraints—the final analytical sample consists of 2,782 innovative service-sector SMEs. This explicit restriction ensures that the subsequent findings and policy implications are properly aligned with the structural characteristics and resource dependencies inherent to the SME segment in an emerging economy.

Data were collected through structured questionnaires and validated by DANE following international protocols. In line with Oslo Manual guidelines, key variables are recorded as dichotomous indicators. This operational logic is consistent with widely used Community Innovation Survey (CIS) applications and supports the application of PLS-SEM to examine how systemic and internal conditions are associated with specific innovation outcomes within the sub-sample of active firms (Bou & Satorra, 2019).

Method of data analysis

Prior to model estimation, the microdata were screened for missing values, internal inconsistencies, and implausible codings. Given the survey-based nature of EDITS VIII and the predominance of dichotomous indicators, the analysis proceeded by retaining complete and valid responses for the indicator sets used to operationalize the composites. Observations were included when they provided non-missing values for the relevant blocks, thereby ensuring consistent construct construction across the estimated models.

The analysis employed Partial Least Squares Structural Equation Modeling (PLS-SEM), implemented using the *seminr* package (v2.3.4) in R (v4.3.1). Estimations were conducted locally on a Windows 11 system. PLS-SEM was selected because it is appropriate for composite-based (formative) model specifications, accommodates categorical and potentially non-normal indicators, and supports predictive-oriented research designs (Hair et al., 2017; Sarstedt et al., 2019; Hair et al., 2021). In addition, the operationalization of key outcomes and inputs using binary incidence indicators is consistent with the logic of Oslo-based innovation surveys and CIS applications, where innovation is frequently measured as the introduction (yes/no) of product and process innovations during a reference period (Bou & Satorra, 2019; Rosário et al., 2024).

The estimation followed the sequential procedure summarised in Figure 2. First, all indicators were recoded into binary variables (0 = No; 1 = Yes) in line with the EDITS VIII questionnaire design. Second, two independent PLS-SEM models were estimated: one for product innovation (PrI) and one for process innovation (PsI). Both models included the same set of exogenous composites—Funding Sources (FS), Institutional Support (IS), and Innovation Investment (II)—to preserve comparability across outcomes while enabling differentiated innovation pathways. This dual-model strategy was adopted after an initial joint specification (with the PrI and PsI models simultaneously modeled as endogenous

constructs) exhibited instability under the binary composite measurement blocks. Estimating separate models improved convergence and interpretability without altering the substantive conceptual framework.

Third, model evaluation followed criteria appropriate for composite (formative) measurement. Indicator collinearity was assessed using variance inflation factors (VIF). Indicator relevance was examined using bootstrapped weights and their percentile confidence intervals from 5,000 resamples. Structural model assessment relied on explained variance (R^2 and adjusted R^2) and bootstrap-based inference for path coefficients (bootstrap means, standard errors, t-statistics, and percentile confidence intervals). Because the endogenous innovation constructs are formed from binary indicators, particular attention was paid to indicator variability to ensure stable resampling-based inference. In the product innovation model, two ultra-rare novelty indicators were aggregated into broader "market novelty" indicators to increase variance while preserving the conceptual intent of novelty beyond the firm level.

Finally, predictive relevance was assessed using Stone–Geisser's Q^2. An Importance–Performance Map Analysis (IPMA) was also conducted to identify constructs that combine higher importance (total effects on the endogenous construct) with comparatively lower performance (average construct scores), thereby supporting a more actionable interpretation of the estimated relationships. The sequential analytical procedure applied in the PLS-SEM models is summarised in Figure 2.

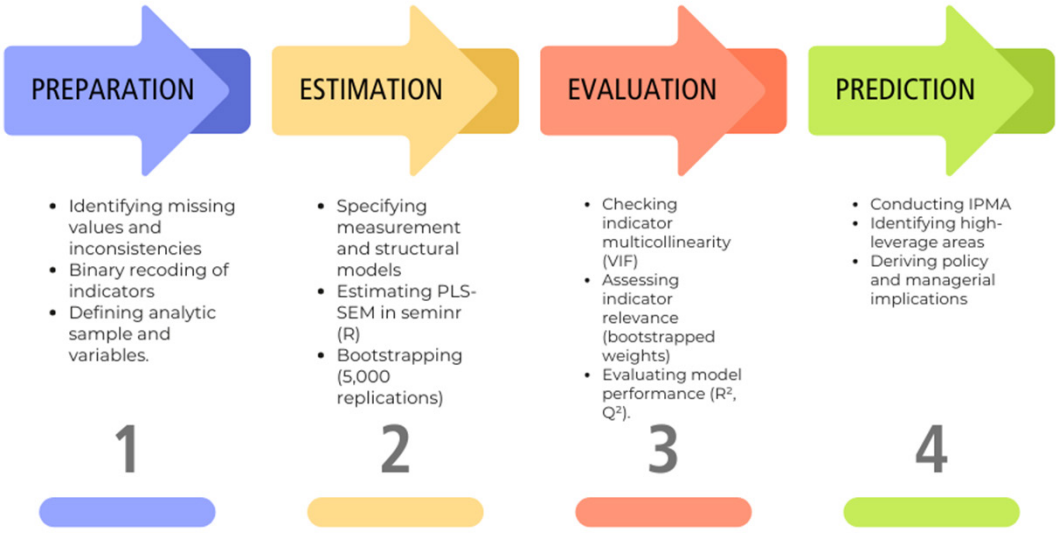

Figure 2. Sequential analytical procedure applied in the PLS-SEM models

Source: Authors' elaboration based on Hair et al. (2021).

RESULTS

Descriptive statistics of constructs

To contextualize the innovation-related profile of the sampled firms, Table 1 reports the frequency and percentage of observations associated with each construct included in the final model. For the innovation outcomes, the table presents a descriptive prevalence measure—coded as 1 when the firm reports at least one indicator within the corresponding innovation block—whereas, in the PLS-SEM estimation, both outcomes are modeled as multi-indicator composites (PrI: four binary indicators; PsI: six binary indicators). Table 1 also summarises the prevalence of institutional support (IS), funding sources (FS), and innovation investment (II) across the 2,782 innovative service-sector firms.

Overall, process innovation (PsI) is substantially more prevalent than product innovation (PrI): 69.2% of firms report at least one process-related innovation indicator, whereas 30.3% report at least one product-related innovation indicator. This pattern suggests that, within the service sector, innovation activity more frequently targets internal operational improvements than market-facing outputs. Regarding institutional support, engagement with public institutions (29.8%) and private-sector actors (28.0%) is relatively common, while academic or research support is less frequent (14.9%).

Support from international organizations/NGOs (4.49%) and training/intermediation entities (7.05%) is comparatively limited, indicating that these channels play a smaller role in the observed innovation dynamics.

With respect to financing, internal resources are the dominant funding channel (76.7%), whereas access to bank loans (9.24%), cooperation/donations (5.57%), and private funds (1.94%) is relatively uncommon. Finally, intangible investment—covering activities such as R&D, training, and software—shows a higher prevalence (72.9%) than tangible investment (41.1%), consistent with the intangible-intensive nature of innovation in service-sector firms.

Table 1. Descriptive statistics of composites and binary indicators (N = 2,782)

Construct	Variable	Description	Count	Total	Percentage (%)
Innovation outcomes	PrI	Firms reporting ≥1 product-innovation indicator (descriptive prevalence)	844	2,782	30.30
Innovation outcomes	PsI	Firms reporting ≥1 process-innovation indicator (descriptive prevalence)	1,925	2,782	69.20
IS – Institutional Support	support_public	Firms that received support from public institutions	830	2,782	29.80
IS – Institutional Support	support_academic	Firms that received support from academic or research institutions	414	2,782	14.90
IS – Institutional Support	support_private	Firms that received support from private-sector actors	780	2,782	28.00
IS – Institutional Support	support_international	Firms that received support from international organizations and/or NGOs	125	2,782	4.49
IS – Institutional Support	support_training	Firms that received support from training/intermediation entities	196	2,782	7.05
FS – Funding Sources	funding_internal	Firms that financed innovation using internal resources	2,135	2,782	76.70
FS – Funding Sources	funding_banks	Firms that financed innovation through bank loans	257	2,782	9.24
FS – Funding Sources	funding_private	Firms that financed innovation using private funds	54	2,782	1.94
FS – Funding Sources	funding_donations	Firms that financed innovation through cooperation and/or donations	155	2,782	5.57
II – Innovation Investment	investment_tangible	Firms that invested in tangible assets for innovation	1,143	2,782	41.10
II – Innovation Investment	investment_intangible	Firms that invested in intangible assets for innovation	2,027	2,782	72.90

Note: PrI is operationalized as a first-order composite with four binary indicators: new_goods_firm, improved_goods_firm, new_goods_market (=1 if national or international new goods =1), and improved_goods_market (=1 if national or international improved goods =1). PsI is operationalized as a first-order composite with six binary indicators capturing innovations in production, organization, marketing, distribution, information management, and administrative practices.

Although firm size and export status were initially considered as additional covariates, preliminary estimations indicated that their inclusion did not improve model stability or explanatory performance for the innovation outcomes examined. Therefore, in line with the principle of parsimony, these variables were excluded from the final structural models.

Evaluation of the measurement model

To assess the adequacy of the measurement model in both innovation specifications, the analysis followed evaluation procedures recommended for composite (formative) constructs in PLS-SEM. Because all latent variables were specified as first-order composites, internal consistency metrics such as Cronbach's alpha, composite reliability (ρC), and average variance extracted (AVE) are not applicable and therefore were not reported. These indices assume reflective measurement and indicator interchangeability, whereas composite indicators represent distinct and non-redundant facets of the construct (Hair et al., 2021).

Accordingly, measurement model evaluation focused on: (i) multicollinearity among indicators, assessed via variance inflation factors (VIF), and (ii) indicator relevance, assessed through bootstrapped weights (5,000 replications). Tables 2a and 2b report the indicator-level VIF values for all composites included in each model.

Two higher-level novelty indicators were extremely rare in the sample. Specifically, only 1.37% of firms reported goods/services new to the national market and 0.11% to the international market, while the corresponding rates for improved goods/services were 1.08% and 0.07%, respectively (Appendix 4). To avoid instability in resampling-based inference while preserving the distinction between firm-level and market-level novelty, these indicators were aggregated into broader market-novelty measures. This approach maintains conceptual consistency with the Oslo Manual classification while ensuring sufficient variability for reliable composite estimation.

Across both models, all VIF values remained well below the conservative threshold of 3.3 (maximum VIF = 1.649), indicating no problematic multicollinearity within the formative blocks and supporting the interpretability of indicators as distinct contributors to their composites. In addition, bootstrapped weights were examined to evaluate the statistical contribution of each indicator. Overall, the weight patterns were consistent with the conceptual specification of each composite and provided an appropriate basis for interpreting the subsequent structural relationships.

Table 2a. Variance Inflation Factors (VIF) for formative indicators — Product innovation model (PrI)

Construct	Indicator	VIF
Product innovation (PrI)	improved_goods_firm	1.06920331
Product innovation (PrI)	improved_goods_market	1.10807788
Product innovation (PrI)	new_goods_firm	1.0778143
Product innovation (PrI)	new_goods_market	1.12395865
Funding Sources (FS)	funding_banks	1.33967903
Funding Sources (FS)	funding_donations	1.53942221
Funding Sources (FS)	funding_internal	1.01734068
Funding Sources (FS)	funding_private	1.40685323
Innovation Investment (II)	investment_intangible	1.04344841
Innovation Investment (II)	investment_tangible	1.04344841
Institutional Support (IS)	support_academic	1.64879251
Institutional Support (IS)	support_international	1.28424585
Institutional Support (IS)	support_private	1.32326737
Institutional Support (IS)	support_public	1.49848142
Institutional Support (IS)	support_training	1.43817195

Source: Authors' elaboration in R.

Table 2b. Variance Inflation Factors (VIF) for formative indicators — Process innovation model (PsI)

Construct	Indicator	VIF
Process innovation (PsI)	new_method_account	1.07662276
Process innovation (PsI)	new_method_distribution	1.07788344
Process innovation (PsI)	new_method_information	1.16348604
Process innovation (PsI)	new_method_marketing	1.05109906
Process innovation (PsI)	new_method_organization	1.18313074
Process innovation (PsI)	new_method_production	1.06894236
Funding Sources (FS)	funding_banks	1.33967903
Funding Sources (FS)	funding_donations	1.53942221
Funding Sources (FS)	funding_internal	1.01734068
Funding Sources (FS)	funding_private	1.40685323
Innovation Investment (II)	investment_intangible	1.04344841
Innovation Investment (II)	investment_tangible	1.04344841
Institutional Support (IS)	support_academic	1.64879251
Institutional Support (IS)	support_international	1.28424585
Institutional Support (IS)	support_private	1.32326737
Institutional Support (IS)	support_public	1.49848142
Institutional Support (IS)	support_training	1.43817195

Source: Authors' elaboration in R.

Because all constructs were specified as formative composites, internal consistency and convergent validity metrics developed for reflective measurement (e.g., Cronbach's alpha, composite reliability, and AVE) were not used as evaluation criteria. Instead, the assessment of the measurement model relied on: (i) indicator collinearity, examined through variance inflation factors (VIF), and (ii) the statistical relevance of indicators, evaluated via bootstrapped indicator weights and 95% confidence intervals (see Appendices 2–3). In formative composites, negative weights may arise due to informational overlap among indicators or suppression effects; accordingly, they should be interpreted as the indicator's net relative contribution, conditional on the presence of the other indicators, and considered jointly with collinearity diagnostics.

Construct distinctiveness and patterns of interrelationships

Given the composite (formative) specification of all constructs, traditional convergent and discriminant validity assessment based on Average Variance Extracted (AVE) and the Fornell–Larcker criterion is not applicable. Therefore, the inter-construct score matrix is not used as a formal validity test but as a diagnostic tool. Instead, construct distinctiveness is supported through three complementary considerations: (i) the deliberate, non-overlapping design of indicators across composites; (ii) the absence of problematic multicollinearity among indicators, as evidenced by the low VIF values reported in Tables 2a and 2b; and (iii) an examination of interrelationship patterns among construct scores as a descriptive diagnostic to identify potential empirical redundancy.

Figure 3 presents the inter-construct scores, showing that the observed associations are directionally consistent with theoretical expectations and do not suggest redundancy among the composites. Because this matrix is used solely for descriptive diagnostics, statistical significance is not reported here. Formal inference is conducted in the structural model analysis (Section 4.4), where path coefficients are evaluated using bootstrapping.

Several patterns emerge from this diagnostic stage. First, Funding Sources and Innovation Investment exhibit a meaningful positive association ($r = 0.655$), suggesting that firms with broader access to financial resources also tend to report a higher incidence of tangible and intangible investment in innovation activities. Institutional Support is likewise positively linked with Innovation Investment ($r = 0.215$), indicating that engagement with external support organizations co-occurs with firms' resource mobilization.

Second, the inter-construct patterns involving innovation outcomes align with the study's conceptual framing. Product innovation (PrI) shows its strongest association with Institutional Support ($r = 0.451$), consistent with the view that linkages with public agencies and universities are especially relevant for market-facing innovation. In contrast, process innovation (PsI) is most strongly associated with Innovation Investment ($r = 0.393$), underscoring the role of resource allocation for internal operational improvements. Finally, the association between PrI and PsI is positive but modest ($r = 0.257$), indicating that they are distinct outcomes. This empirical pattern further validates the decision to estimate separate structural models to capture the distinct association patterns characterizing each innovation type.

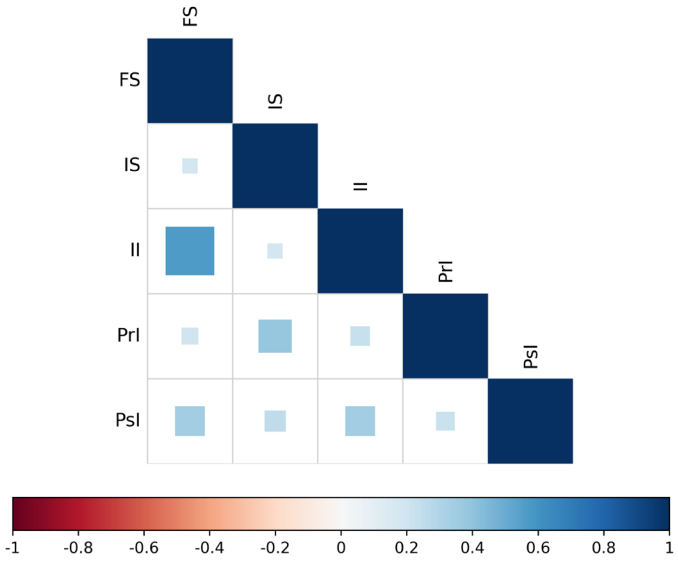

Figure 3. Matrix of interrelationships between construct scores

Structural model estimation

Consistent with the composite-based specification of the explanatory constructs, the estimated structural coefficients capture the aggregated effects of funding sources and institutional support rather than the isolated contributions of individual sources. This modeling choice reflects the systemic and complementary nature of financial and institutional resources in shaping innovation outcomes in service-sector firms.

Product innovation model

To estimate the structural relationships between the explanatory constructs and product innovation, a PLS-SEM model was specified using the *seminr* package in R. The measurement model incorporated three first-order composites—Funding Sources (FS), Institutional Support (IS), and Innovation Investment (II)—each operationalized using non-redundant binary indicators derived from the EDITS VIII dataset.

The endogenous construct, Product Innovation (PrI), was specified as a first-order composite measured by four dichotomous indicators, capturing the introduction of new or significantly improved goods/services at the firm level and at broader market novelty levels. This specification reflects an aggregation of low-frequency novelty indicators to ensure sufficient variability and statistical stability in the estimation.

The structural model included direct paths from FS, IS, and II to PrI and was estimated using 2,782 observations from innovative firms in the service sector. Table 3 reports the standardized path coefficients and the model's explanatory power.

Table 3. PLS-SEM Structural Model Results – Product Innovation

Path	Coefficient	Bootstrap mean	Std. Dev.	t-statistic	p-value	95% CI (2.5%–97.5%)
FS → Product Innovation (PrI)	0.071	0.075	0.0289	2.46	0.014	[0.019, 0.132]
IS → Product Innovation (PrI)	0.416	0.419	0.0234	17.74	<0.001	[0.373, 0.464]
II → Product Innovation (PrI)	0.138	0.136	0.0295	4.67	<0.001	[0.078, 0.193]
R^2	0.246					
Adj. R^2	0.246					

Source: Authors' estimation in R with seminr (v2.3.4), 5,000 bootstrap resamples.

Overall, the model explains 24.6% of the variance in product innovation ($R^2 = 0.246$), which represents a meaningful level of explanatory power given the exploratory scope of the study and the binary nature of the indicators. Among the constructs, Institutional Support (IS) shows the strongest association with product innovation ($\beta = 0.416$), highlighting the relevance of engagement with public programs, universities, and support organizations for product-oriented innovation in service-sector firms. Innovation Investment (II) is also positively related to product innovation ($\beta = 0.138$), suggesting that allocating resources to tangible and intangible innovation assets contributes to the introduction of new or improved products/services. By contrast, Funding Sources (FS) exhibits the smallest coefficient ($\beta = 0.071$), indicating that variation in financing modalities is less strongly associated with product innovation than institutional linkages and innovation-oriented investment in this sample.

For statistical inference, a bootstrapping procedure with 5,000 resamples was implemented after aggregating low-frequency novelty indicators to ensure sufficient variability in the measurement model. The bootstrapped results confirm the statistical significance of all structural paths, with confidence intervals that exclude zero. Accordingly, the estimated coefficients can be interpreted as statistically supported associations within the composite-based PLS-SEM framework. Figure 4 provides a graphical representation of the estimated structural model.

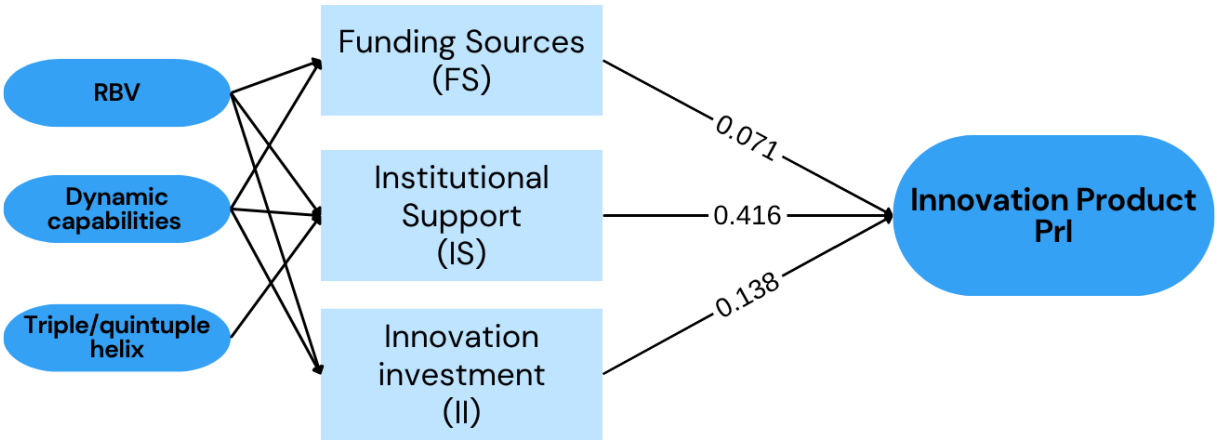

Figure 4. Structural model for product innovation (PLS-SEM standardized path coefficients)

Process innovation model

To examine the correlates of process innovation, a second structural model was estimated using the same three first-order composites: Funding Sources (FS), Institutional Support (IS), and Innovation Investment (II). The endogenous construct, Process Innovation (PsI), was specified as a composite measured by six binary indicators reflecting innovations in production methods, organizational routines, marketing techniques, distribution systems, information management, and administrative practices. The model was estimated using the same analytical sample of 2,782 innovative service-sector firms from the EDIT VIII dataset. The standardized path coefficients and explanatory power, indicating the strength of these associations within the innovation-active sub-sample, are reported in Table 4.

Table 4. PLS-SEM Structural Model Results – Process Innovation

Path	Coefficient	Bootstrap mean	Std. Dev.	t-statistic	p-value	95% CI (2.5%–97.5%)
FS → Process Innovation (PsI)	0.079	0.081	0.0265	2.99	<0.001	[0.027, 0.133]
IS → Process Innovation (PsI)	0.203	0.204	0.0234	8.67	<0.001	[0.157, 0.250]
II → Process Innovation (PsI)	0.371	0.370	0.0257	14.44	<0.001	[0.321, 0.422]
R^2	0.272					
Adj. R^2	0.271					

Source: Authors' estimation in R with seminr (v2.3.4); bootstrapping with 5,000 resamples.

Overall, the model explains 27.2% of the variance in process innovation outcomes, indicating a moderate explanatory capacity that slightly exceeds the product innovation model. Among the constructs, Innovation Investment (II) shows the strongest association with process innovation (β = 0.371), suggesting that firms allocating tangible and intangible resources—such as equipment, training, and software—are more likely to report internal innovation activities. Institutional Support (IS) also exhibits a positive association (β = 0.203), indicating that engagement with external support organizations is linked to process innovation, plausibly through channels such as technical assistance, knowledge diffusion, and skills development. Funding Sources (FS) presents the smallest coefficient (β = 0.079), implying that variation in financing modalities is less strongly associated with process innovation than innovation-oriented investment and institutional linkages in this sample.

For statistical inference, a bootstrapping procedure with 5,000 resamples was implemented. The results indicate that all structural paths are statistically significant, with confidence intervals that exclude zero (Table 4), supporting the robustness of the estimated relationships within the composite-based PLS-SEM framework. Figure 5 summarises the estimated structural relationships and the measurement specification for the Process Innovation (PsI) composite.

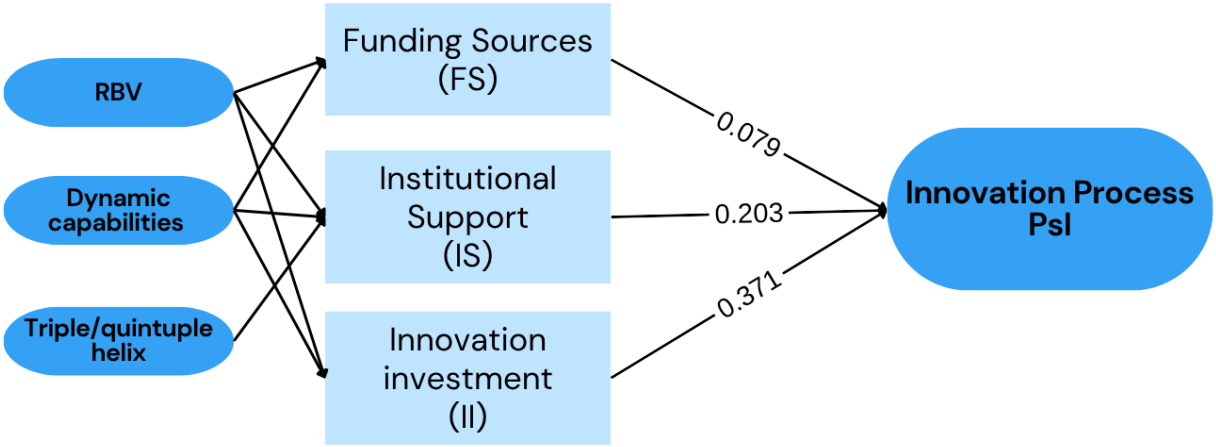

Figure 5. PLS-SEM Model for Process Innovation

Predictive relevance and importance-performance analysis

To evaluate the predictive capability of the estimated PLS-SEM models, Stone–Geisser's Q^2 values were computed using a blindfolding procedure. The results indicate positive predictive relevance for both endogenous constructs, with Q^2 = 0.125 for Product Innovation (PrI) and Q^2 = 0.192 for Process Innovation (PsI). As both values exceed the recommended threshold of zero, the models demonstrate out-of-sample predictive relevance appropriate for an exploratory assessment of innovation outcomes in emerging-economy settings (Hair et al., 2019).

In addition, an Importance–Performance Map Analysis (IPMA) was conducted to identify constructs that combine relatively high importance (i.e., total effects on the endogenous construct) with comparatively low performance (i.e., average construct score). This complementary diagnostic facilitates a more actionable interpretation of the model results by highlighting where improvements could yield greater potential gains in innovation outcomes. Table 5 reports the IPMA results for both the product and process innovation models.

Table 5. Importance–Performance Analysis (IPMA) for Product and Process Innovation

Construct	Mean score	Importance on PrI	Importance on PsI
FS	0.430	0.075	0.079
IS	0.321	0.406	0.203
II	0.556	0.139	0.371

Source: Authors' calculation in R.

The IPMA results point to differentiated leverage areas across innovation outcomes. For product innovation, Institutional Support (IS) emerges as the most important construct (importance = 0.406) while also exhibiting the lowest performance (mean score = 0.321). This configuration positions IS as a high-leverage domain where strengthening linkages with public agencies, universities, and support organizations could be particularly relevant for enhancing product-oriented innovation. For process innovation, Innovation Investment (II) shows the highest importance (importance = 0.371) and also the highest performance (mean score = 0.556), reinforcing the central role of tangible and intangible resource allocation—such as equipment, training, and digital and knowledge-related investments—in internal operational improvements.

By contrast, Funding Sources (FS) is comparatively less important in both models (0.075 for PrI; 0.079 for PsI) and has a mid-range performance level (mean score = 0.430). This pattern suggests that, within the observed institutional and market context, financing modalities alone are less closely aligned with innovation outcomes than institutional linkages and innovation-oriented investment, and that their contribution may depend on how effectively financial resources are translated into capability-building inputs.

Figure 6 summarises these findings by mapping each construct according to its relative importance and empirical performance, thereby offering a practical lens for prioritizing managerial and policy interventions.

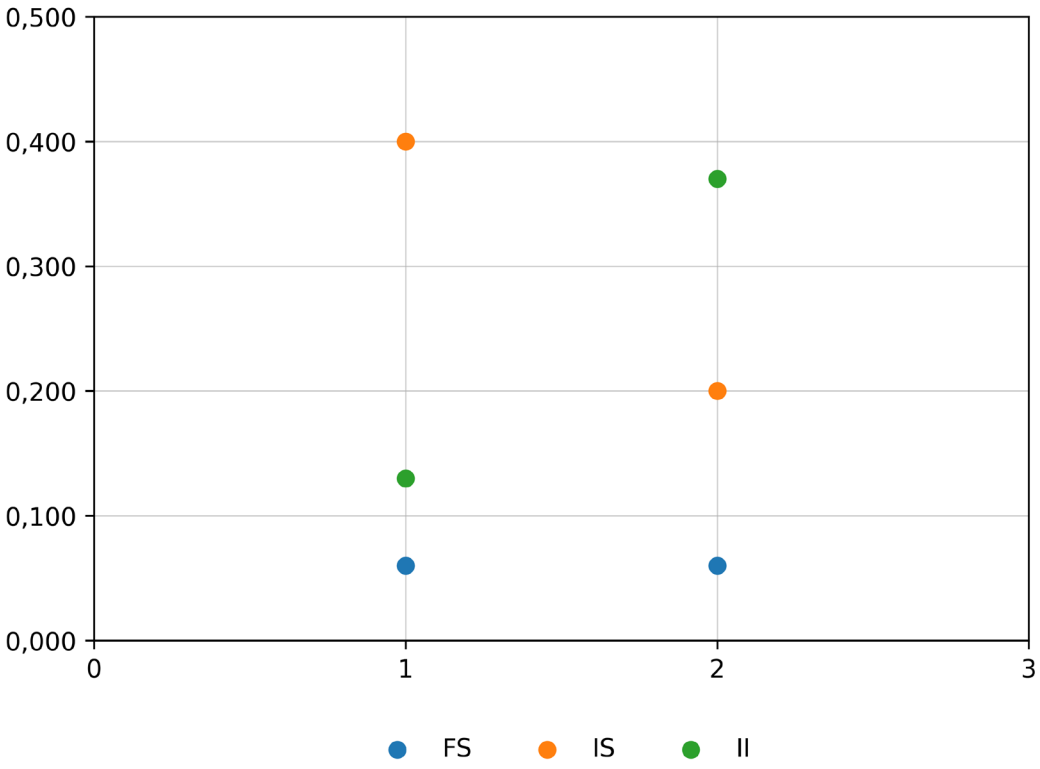

Figure 6. Importance–Performance Map (IPMA) for Product and Process Innovation

DISCUSSION

This study contributes to the literature on innovation in emerging economies by providing empirical evidence on how aggregated (formative) funding structures, institutional linkages, and innovation-oriented investment are associated with two distinct innovation outcomes among innovative service-sector SMEs in Colombia. By estimating two independent PLS-SEM models—one for product innovation and another for process innovation—the analysis addresses the conceptual and empirical argument that these outcomes are related but not interchangeable, particularly in service sectors where innovation frequently materializes through both market-facing offerings and internal organizational and digital upgrading (Busom & Vélez-Ospina, 2017; Pertuz & Ojeda Ramírez, 2023). In addition, operationalizing innovation outcomes using binary incidence indicators is consistent wits and widely used CIS applications, in which innovation is typically measured as a dichotomous "introduced versus not introduced" outcome within a given reference period (Bou & Satorra, 2019; Rosário et al., 2024). This approach, therefore, captures the occurrence of innovation among firms reporting innovation activities rather than the magnitude of innovation outputs.

A central finding of the study is the differentiated pattern of associations observed across innovation outcomes. Institutional Support (IS) shows the strongest association with product innovation (β = 0.416), whereas Innovation Investment (II) exhibits the strongest association with process innovation (β = 0.371). Although the two models have comparable explanatory power (R^2 = 0.246 for product innovation and R^2 = 0.272 for process innovation), their internal structures reveal theoretically meaningful differences. Because FS, IS, and II are specified as composite constructs, the estimated coefficients capture the joint association of their underlying indicators with innovation outcomes rather than the isolated effect of individual funding mechanisms or institutional actors.

The prominence of institutional linkages in explaining product innovation is consistent with systemic perspectives of innovation, particularly in emerging-economy contexts where firms often rely on external knowledge channels to

complement limited internal research capabilities. In Colombia, empirical evidence suggests that public support and institutional infrastructure for innovation play a significant role in shaping firms' innovation trajectories, including in the service sector (Busom & Vélez-Ospina, 2017). For service SMEs, access to universities, innovation intermediaries, technical assistance, and market-based knowledge sources can accelerate learning, validation, and commercialization. Recent empirical evidence indicates that innovative Colombian service firms combine internal knowledge with market-based sources and technical assistance, while university knowledge can differentiate firms' innovation profiles (Pertuz & Ojeda Ramírez, 2023). From this perspective, Institutional Support functions not merely as a source of resources but also as an ecosystem mechanism that expands firms' knowledge access and strengthens their absorptive and commercialization capabilities in contexts where internal research infrastructure is limited.

In contrast, the stronger association between innovation investment and process innovation reflects the importance of internal capability development and resource reconfiguration for operational improvements. Process innovation in service SMEs often involves investments in intangible assets, such as training, organizational redesign, digital infrastructure, software, and information systems. These investments facilitate incremental improvements in service delivery, administrative processes, and information management, thereby enhancing organizational efficiency and adaptability. This interpretation aligns with evidence showing that discrete technological breakthroughs drive less intangible-intensive innovation than sustained investments in organizational capabilities and learning processes. Moreover, intangible assets are often difficult to collateralize, particularly for SMEs, which influences both the structure of financing and the mechanisms through which investment translates into innovation outcomes (Norkio, 2024). In this context, Innovation Investment represents the internal accumulation and deployment of innovation-related inputs that support continuous process upgrading.

Funding Sources (FS) shows a positive but comparatively modest association with both innovation outcomes (β = 0.071 for product innovation and β = 0.079 for process innovation). Substantively, this result suggests that financing—when conceptualized as an aggregated structure—functions primarily as an enabling condition rather than a direct explanatory factor of innovation outcomes. This interpretation is consistent with empirical evidence indicating that self-financing remains highly prevalent among Colombian SMEs and is closely associated with innovation activities, while external financing is often constrained by risk aversion, information asymmetries, and limited specialized financial instruments (Gálvez-Albarracín et al., 2018). Additional evidence highlights that financial barriers continue to influence firms' innovation performance and interact with knowledge networks and human capital conditions (Barrios et al., 2022). International research similarly suggests that innovative SMEs frequently face persistent frictions in accessing suitable financing instruments, particularly under conditions of uncertainty, reinforcing the idea that financial availability alone does not automatically translate into innovation unless it is effectively transformed into innovation investment and complemented by institutional support (Cowling et al., 2024).

The empirical distinction between product and process innovation is further supported by the moderate correlation between the two constructs (r = 0.257), which reinforces the methodological decision to estimate separate models. Conceptually, this distinction suggests that product innovation outcomes in service SMEs are more strongly influenced by ecosystem connectivity and institutional interfaces, whereas process innovation is more closely linked to internal investment intensity and the accumulation of intangible capabilities. From a policy perspective, this differentiation implies that uniform innovation support instruments may be insufficient: strengthening institutional bridges and specialized support infrastructures may be particularly relevant for product innovation, while policy instruments that encourage sustained investment in innovation capabilities—especially in intangible assets—may be more effective in promoting process upgrading.

The empirical results provide differentiated support for the proposed hypotheses. Hypotheses H1a and H1b receive support, as Funding Sources (FS) are positively associated with both product and process innovation, although the relatively small coefficients suggest a facilitating rather than dominant influence (Gálvez-Albarracín et al., 2018). Hypothesis H2a receives strong support, with Institutional Support showing the largest association with product innovation outcomes, highlighting the importance of institutional knowledge channels and innovation ecosystems in the Colombian service sector (Busom & Vélez-Ospina, 2017; Pertuz & Ojeda Ramírez, 2023). Finally, hypothesis H3b receives strong empirical support, as Innovation Investment shows the strongest association with process innovation, consistent with the capability-building role of intangible investment and internal implementation capacity (Norkio, 2024).

Overall, the findings underscore a key contextual insight for emerging economies: innovation in service-sector SMEs is less a linear outcome of increased financial availability and more a function of how financial resources are transformed

into innovation investment and combined with institutional linkages that enable learning, legitimacy, and access to complementary knowledge resources. From a policy perspective, strengthening institutional connectivity and mechanisms that support capability-building investment may therefore be as important as expanding financial channels, particularly in service sectors characterized by asymmetric access to resources and fragmented innovation support infrastructures (Busom & Vélez-Ospina, 2017; Cowling et al., 2024).

CONCLUSION

This study examines how aggregated funding structures, institutional support, and innovation-oriented investment relate to product and process innovation outcomes among innovation-active service-sector SMEs in Colombia. Using firm-level microdata from the EDITS VIII survey and estimating two PLS-SEM models, the analysis provides new empirical insights into how financial and institutional resources are associated with innovation outcomes in an emerging-economy service context.

A first contribution of the study is theoretical. By integrating the resource-based view, dynamic capabilities theory, and the Triple/Quadruple Helix perspectives within a composite-based SEM framework, the study proposes a holistic analytical model linking financial structures, institutional ecosystems, and investment patterns to distinct innovation outcomes. The results suggest that these domains operate as complementary resource configurations rather than independent explanatory factors. In particular, the findings indicate that institutional support is more strongly associated with product innovation, whereas innovation investment appears more strongly related to process innovation, highlighting differentiated innovation pathways among innovation-active service-sector SMEs.

A second contribution is empirical. Evidence from Colombian service-sector SMEs engaged in innovation activities indicates that institutional linkages are closely associated with product innovation outcomes, suggesting that connections with universities, support institutions, and market actors may facilitate access to knowledge and commercialization opportunities. In contrast, internal investment in innovation-related assets—particularly intangible resources—appears more strongly associated with process innovation, reflecting the importance of internal capability development and operational upgrading. Funding structures exhibit a positive but comparatively weaker association with both innovation outcomes, suggesting that financial resources may primarily serve as enabling conditions rather than direct explanatory factors.

A third contribution relates to methodological advancement. By operationalizing funding sources, institutional support, and innovation investment as formative composite constructs and modeling product and process innovation separately, the study provides a structured approach for capturing the multidimensional nature of innovation inputs in emerging-economy contexts. This approach allows the analysis to reflect the aggregated configuration of financial and institutional resources available to firms rather than focusing on isolated indicators.

From a policy and managerial perspective, the findings suggest that innovation support policies for innovation-active service-sector SMEs should move beyond purely financial instruments. Strengthening institutional linkages—such as collaboration with universities, technical assistance organizations, and innovation intermediaries—appears particularly relevant for fostering product innovation. At the same time, policies that encourage sustained investment in innovation-related assets, including training, digital infrastructure, and organizational capabilities, may be more conducive to supporting process innovation and operational upgrading.

Finally, several limitations should be acknowledged. The study relies on cross-sectional survey data, which limits causal inference regarding the direction of relationships between financing structures and innovation outcomes. Moreover, the measurement of innovation outcomes relies on binary indicators that capture the occurrence of innovation rather than its economic magnitude or technological depth. These limitations suggest that innovation in emerging economies should be understood not as a single process but as a set of differentiated pathways shaped by the interaction between financial structures, institutional ecosystems, and internal capability development. Future research could extend this approach by incorporating longitudinal data, intensity-based innovation indicators, and comparative analyses across sectors or countries to further explore the dynamics linking financial structures, institutional ecosystems, and innovation performance.

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Appendix 1. Operationalization of constructs: Latent variables, descriptions, and EDITS VIII survey codes

Construct	Indicator (binary)	Description	EDITS Code
PrI – Product Innovation	new_goods_firm	New goods or services for the firm (already available in national/international markets)	I1R1C1N
	improved_goods_firm	Improved goods or services for the firm (already available in national/international markets).	I1R1C1M
	new_goods_market	New goods/services with market novelty (1 if national or international novelty = 1)	I1R2C1N and I1R3C1N
	improved_goods_market	Improved goods/services with market novelty (1 if national or international novelty = 1)	I1R2C1M and I1R3C1M
PsI – Process Innovation	new_method_production	New or improved methods for delivery service or goods production.	I1R4C1
	new_method_organization	New or improved organizational methods within the firm.	I1R5C1
	new_method_marketing	New or improved marketing techniques.	I1R6C1
	new_method_distribution	New or improved distribution, delivery, or logistics systems.	I1R8C1
	new_method_information	New or improved information processing or communication methods.	I1R9C1
	new_method_account	New or improved accounting or administrative operations methods.	I1R10C1
FS – Funding Sources	funding_internal	Own financial resources.	III1R1C1, III1R1C2
	funding_banks	Bank loans from domestic or international institutions.	III1R4C1–III1R4C4
	funding_private	Private equity or funding from other companies (domestic or international).	III1R6C1–III1R6C4
	funding_donations	Funds from cooperation or donations.	III1R7C1–III1R7C4
II – Innovation Investment	investment_tangible	Machinery, equipment, or facilities acquired for innovation purposes.	II1R3C1, II1R3C2, II1R11C1, II1R11C2
	investment_intangible	Internal/external R&D, ICT, software, marketing, intellectual property, technical assistance, training, etc.	II1R1C1–II1R12C2
IS – Institutional Support	support_public	Public and governmental institutions (e.g., ministries, SENA, INNPulsa, Colombia Productiva).	V2R1C1–V3R12C1
	support_academic	Universities, research centers, technology parks, and academic entities.	V2R7C1–V3R10C1
	support_private	Private sector entities: clients, suppliers, business groups, consultants.	V2R15C1–V3R5C1
	support_international	International organizations and NGOs.	V2R17C1, V3R11C1
	support_training	Technical training entities, regional science and technology councils (CODECyT), regional competitiveness commissions.	V2R13C1, V2R14C1, V2R19C1

Note: The sequence of process innovation indicators follows the original EDITS VIII questionnaire structure. After item I1R6C1 (marketing methods), the survey includes I1R7C1, which refers to a follow-up question on marketing innovation rather than a distinct type of process innovation. Consequently, the next indicator corresponding to a different innovation category is I1R8C1 (distribution and logistics methods). The numbering therefore reflects the original questionnaire coding rather than a missing variable.

Appendix 2. Bootstrapped indicator weights (PrI model)

Construct	Indicator	Weight	SE	t	CI 2.5%	CI 97.5%
Product Innovation (PrI)	new_goods_firm	0.495***	0.028	17.429	0.439	0.551
Product Innovation (PrI)	improved_goods_firm	0.445***	0.030	15.013	0.386	0.502
Product Innovation (PrI)	new_goods_market	0.399***	0.034	11.621	0.330	0.464
Product Innovation (PrI)	improved_goods_market	0.276***	0.038	7.332	0.199	0.345
Funding Sources (FS)	funding_internal	0.636***	0.066	9.577	0.515	0.773
Funding Sources (FS)	funding_banks	0.281***	0.063	4.478	0.145	0.393
Funding Sources (FS)	funding_private	-0.122***	0.047	-2.592	-0.216	-0.033
Funding Sources (FS)	funding_donations	0.579***	0.062	9.316	0.446	0.688
Institutional Support (IS)	support_public	0.544***	0.031	17.613	0.485	0.605
Institutional Support (IS)	support_academic	0.484***	0.017	27.805	0.451	0.516
Institutional Support (IS)	support_private	0.259***	0.013	19.248	0.233	0.286
Institutional Support (IS)	support_international	0.286***	0.021	13.333	0.245	0.328
Institutional Support (IS)	support_training	0.277***	0.017	16.440	0.242	0.309
Innovation Investment (II)	investment_tangible	0.797***	0.026	31.066	0.744	0.844
Innovation Investment (II)	investment_intangible	0.462***	0.033	13.963	0.396	0.526

Note: Weights were estimated using bootstrapping with 95% confidence intervals. *** p < 0.01; ** p < 0.05; * p < 0.10 (normal approximation based on the t-statistic).

Appendix 3. Bootstrapped indicator weights (PsI model)

Construct	Indicator	Weight	SE	t	CI 2.5%	CI 97.5%
Process Innovation (PsI)	new_method_production	0.339***	0.017	19.460	0.305	0.372
Process Innovation (PsI)	new_method_ organization	0.343***	0.012	28.326	0.319	0.366
Process Innovation (PsI)	new_method_marketing	0.274***	0.016	17.346	0.242	0.304
Process Innovation (PsI)	new_method_distribution	0.209***	0.015	13.699	0.178	0.239
Process Innovation (PsI)	new_method_information	0.413***	0.015	28.367	0.385	0.442
Process Innovation (PsI)	new_method_account	0.517***	0.018	29.124	0.481	0.552
Funding Sources (FS)	funding_internal	0.756***	0.034	22.048	0.687	0.822
Funding Sources (FS)	funding_banks	0.261***	0.031	8.465	0.197	0.318
Funding Sources (FS)	funding_private	0.111***	0.031	3.533	0.047	0.171
Funding Sources (FS)	funding_donations	0.323***	0.030	10.575	0.258	0.380
Institutional Support (IS)	support_public	0.665***	0.023	28.893	0.620	0.710
Institutional Support (IS)	support_academic	0.489***	0.017	29.469	0.457	0.522
Institutional Support (IS)	support_private	0.349***	0.023	15.283	0.308	0.397
Institutional Support (IS)	support_international	0.250***	0.023	10.651	0.202	0.293
Institutional Support (IS)	support_training	0.209***	0.022	9.414	0.163	0.249
Innovation Investment (II)	investment_tangible	0.410***	0.026	15.677	0.357	0.459
Innovation Investment (II)	investment_intangible	0.832***	0.019	43.332	0.794	0.869

Note: Weights were estimated using bootstrapping with 95% confidence intervals. *** p < 0.01; ** p < 0.05; * p < 0.10 (normal approximation based on the t-statistic).

Appendix 4. Prevalence of original product innovation novelty indicators

Indicator	Count	Total	Percentage (%)
new_goods_firm	598	2,782	21.50
new_goods_national	38	2,782	1.37
new_goods_international	3	2,782	0.11
improved_goods_firm	423	2,782	15.20
improved_goods_national	30	2,782	1.08
improved_goods_international	2	2,782	0.07

Note: National and international novelty indicators were subsequently aggregated into the broader variables *new_goods_market* and *improved_goods_market* for the estimation of the Product Innovation composite.

Biographical notes

Yaneth P. Romero-Alvarez is a Ph.D. in Innovation and a Full Professor at Universidad de Sucre (Colombia). Her research integrates innovation, financing strategies, and technological capabilities in SMEs, with a particular focus on developing and peripheral regions. She has an extensive background in financial analysis, project evaluation, and public investment, and has contributed to studies on innovation determinants using econometric techniques, including logistic regression and PLS-SEM, applied to large-scale datasets. Her work emphasizes the role of financial structures and institutional environments in shaping innovation outcomes and regional development.

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Author Contributions Statement

Yaneth P. Romero-Alvarez: Conceptualization, Data Curation, Formal Analysis, Methodology, Investigation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing.
Katherinne Salas-Navarro: Conceptualization, Supervision, Investigation, Writing – Review & Editing. **Lisana B. Martinez:** Resources, Supervision, Writing – Review & Editing.

Conflicts of Interest

The authors declare no conflicts of interest.

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