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Technology and Depopulation in Rural Areas: Can Connectivity Sustain SME Performance?

Tecnología y despoblación en las zonas rurales: ¿Puede la conectividad sostener el rendimiento de las pymes?

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Abstract
This study examines whether access to next-generation telecommunications infrastructure, such as 5G, can mitigate the adverse effects of depopulation on the performance of SMEs located in rural areas. The adoption of digital technologies associated with Industry 4.0, including big data analytics, cloud computing, and artificial intelligence, enables firms to optimize processes, enhance competitiveness, and ultimately improve profitability. However, depopulation may hinder digital transformation by limiting access to adequate telecommunications infrastructure in rural areas. In this context, the study offers a new perspective on how environmental conditions and local resources shape economic activity. Using quantitative analysis, the findings show that advanced connectivity is not merely a technical improvement but a critical factor capable of offsetting the adverse effects of depopulation on business performance. These results provide important insights into the resilience of rural SMEs and offer a strategic basis for the design of development policies in depopulated areas.

Keywords: depopulation; SMEs; telecommunications infrastructure; digitalization; Industry 4.0; firm performance
JEL Classification: J10; M10; L96; O32; O33

Resumen
Este estudio examina si el acceso a infraestructuras de telecomunicaciones de nueva generación, como el 5G, puede mitigar los efectos adversos de la despoblación sobre el rendimiento de pymes ubicadas en áreas rurales. La adopción de tecnologías digitales asociadas con la Industria 4.0, incluidas la analítica de big data, la computación en la nube y la inteligencia artificial, permite a las empresas optimizar procesos, mejorar su competitividad y, en última instancia, aumentar su rentabilidad. Sin embargo, la despoblación puede obstaculizar la transformación digital al limitar el acceso a infraestructuras de telecomunicaciones adecuadas en las zonas rurales. En este contexto, el estudio ofrece una nueva perspectiva sobre cómo las condiciones del entorno y los recursos locales configuran la actividad económica. Mediante un análisis cuantitativo, los resultados muestran que la conectividad avanzada no constituye únicamente una mejora técnica, sino un factor crítico capaz de compensar los efectos adversos de la despoblación sobre el rendimiento empresarial. Estos hallazgos aportan información relevante sobre la resiliencia de las pymes rurales y ofrecen una base estratégica para el diseño de políticas de desarrollo en territorios afectados por la despoblación.

Palabras clave: despoblación; pymes; infraestructura de telecomunicaciones; digitalización; Industria 4.0; rendimiento empresarial
Clasificación JEL: J10; M10; L96; O32; O33

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1. Introduction

Currently, depopulation is a global phenomenon that disproportionately affects rural areas, reshaping their demographic structure and constraining their economic development (Pinilla & Sáez, 2017; Maeso, 2020). In these territories, population decline is often accompanied by structural constraints, such as shortages of skilled labor and deficiencies in physical infrastructure and public services, which hinder productive activity and weaken the local business ecosystem (Collantes & Pinilla, 2020; Orduña & Sabater, 2022). The local context in which small and medium-sized enterprises (SMEs) operate has been shown to play a fundamental role in their economic development (López-Taravilla et al., 2023).

In this context, the literature has shown that digital transformation enables firms to improve efficiency and productivity by reducing costs, optimizing processes, enhancing decision-making, and facilitating access to new markets (Goldfarb & Tucker, 2019). Previous research has also demonstrated that internet use encourages the adoption of new practices and technologies, particularly in environments where access to information is limited, such as rural areas (Yang, 2023). However, the effective adoption of advanced digital technologies, including big data analytics and artificial intelligence (AI), requires both internal capabilities and external enabling factors, particularly telecommunications infrastructure capable of ensuring adequate coverage and quality of service (Bag et al., 2021; López-Taravilla et al., 2024). This issue is especially relevant in depopulated rural areas, where connectivity gaps tend to delay digitalization (Orduña & Sabater, 2022), thereby constraining SME growth. In this regard, digital connectivity, particularly through the deployment of advanced networks such as 5G, emerges as a key factor shaping firms' ability to adapt to increasingly digitalized environments.

As postulated by Resource Dependence Theory (Pfeffer & Salancik, 1978) and supported by studies such as those by Dicken and Malmberg (2011) and Backman and Palmberg (2015), organizations depend on external resources within their environment to survive and prosper, and digital connectivity has become one such critical resource for accessing markets and knowledge. Although previous research has shown that digitalization improves business performance by reducing costs (Yang, 2023) and promoting industrial modernization (Chao et al., 2021), studies examining access to favorable technological and structural conditions across different geographical areas have largely overlooked the role of depopulation. The present study extends this line of research by explicitly integrating depopulation as a critical contextual factor shaping digitalization processes and their impact on firm performance.

In particular, it remains unclear whether improvements in connectivity translate into tangible economic benefits for SMEs located in depopulated rural areas or whether the structural constraints of these environments limit their effectiveness. Addressing this issue is especially relevant in the current context, as governments are increasing investment in digital infrastructure to promote economic development and territorial cohesion. If connectivity contributes to improving SME performance in depopulated areas, this would support the view that digital infrastructure can act as a compensatory mechanism for territorial disadvantages, with direct implications for both business decision-making and the design of public policies aimed at regional development.

Based on these premises, the objective of this study is to evaluate the extent to which access to advanced network coverage, specifically 5G networks, is associated with differences in firm performance and whether such networks mitigate the adverse effects of depopulation on rural SMEs. Accordingly, this paper addresses the following research question: To what extent are changes in 5G coverage in depopulated rural areas associated with variations in SME performance?

To address this research question, empirical evidence is drawn from the analysis of a dataset comprising SMEs located in depopulated rural municipalities in Castilla-La Mancha. The dataset was constructed by combining firm-level financial information from the SABI database (Bureau van Dijk) with data on 5G coverage and territorial characteristics obtained from institutional sources (SETELECO and AEAT). The analysis covers the period 2021–2023, thereby capturing the evolution of 5G deployment in the region. The variables included in the analysis comprise measures of firm performance, proxied by variations in return on assets (ROA); indicators of connectivity based on changes in 5G coverage; and territorial variables reflecting the degree of depopulation across municipalities. In addition, control variables related to firm size and firm age are incorporated. For the empirical analysis, ordinary least squares (OLS) regression models are estimated to examine the relationship between variations in firm performance and changes in 5G coverage while accounting for the role of depopulation. Specifically, different model specifications are employed to assess both the direct association between connectivity and firm performance and the interaction between connectivity and the territorial context.

This approach makes it possible to examine whether the deployment of advanced networks such as 5G is associated with changes in firm performance across different levels of depopulation, as well as to evaluate its potential role as a mechanism for mitigating the structural disadvantages of rural environments.

Through this approach, the study contributes to a better understanding of how territorial conditions shape economic activity while also providing a solid basis for the design of more effective rural development policies. The findings further suggest that investment in telecommunications infrastructure should be regarded not merely as a technical matter but as a fundamental strategic decision. Ultimately, the study positions connectivity infrastructure as an essential instrument for maintaining the economic viability of rural areas and ensuring their integration into the global market. In addition, the study contributes to the literature by providing micro-level empirical evidence on how changes in connectivity interact with territorial conditions to explain firm performance, thereby addressing dimensions that have largely been examined separately in previous research.

2. Theoretical Framework

2.1. Depopulation and Rural Development

Depopulation is a global phenomenon affecting both developed and developing countries (Maeso, 2020) and reflects the territorial and demographic transformations experienced by regions over time (Pinilla & Sáez, 2017). This process can be attributed to two main factors: first, the migration of inhabitants from rural areas to urban centers in search of better employment opportunities and services; and second, natural population decline resulting from high mortality rates and low birth rates (Pinilla & Sáez, 2017). Among the main drivers of rural depopulation are the search for higher wages, improved access to healthcare services, insufficient infrastructure and public services in rural areas, and the lack of incentives for local business development. Furthermore, limited economic diversification in rural areas, which typically offer lower wages than urban environments, has contributed to intensifying this trend (Collantes & Pinilla, 2020).

Historically, processes of industrialization and urbanization have reinforced this dynamic by concentrating economic activity in urban areas, thereby increasing demand for labor (Pinilla & Sáez, 2017). As a result, migration flows have predominantly involved young individuals of working age (Pinilla & Sáez, 2017), while many women have moved in search of improved professional and personal opportunities (Collantes & Pinilla, 2020), further contributing to declining birth rates in rural areas. This phenomenon has affected territories unevenly, with municipalities located farther from urban centers being the most severely impacted. In such areas, population decline has reduced infrastructure provision, the availability of public services and resources, and demand for production factors, all of which are key elements shaping firms' economic activity (Collantes & Pinilla, 2020).

Against this backdrop, these challenges become even more pronounced in the context of rural depopulation. The literature shows that depopulation is not merely a demographic phenomenon but is also associated with structural constraints affecting both the social and economic dynamics of rural areas, including limited economic diversification and restricted access to infrastructure and services. In this regard, Becerra and Pérez González (2025) argue that these territories are characterized by scarce resources and poorly coordinated development plans, which hinder stable economic activity and limit their capacity to retain population and attract new residents. Similarly, Magdalena (2025) notes that conditions such as low population density and high logistics costs exert persistent structural pressure on local firms, thereby constraining their growth capacity. These constraints are consistent with Resource Dependence Theory (Pfeffer & Salancik, 1978), which suggests that firms depend not only on internal resources but also on access to external resources available within their environment.

At the aggregate level, the World Bank (2024) reports that the rural population accounted for approximately 42% of the global population in 2024. However, across Organisation for Economic Co-operation and Development (OECD) countries, rural population decline has been observed in numerous regions, particularly those located far from urban centers, with projections indicating a substantial reduction in the coming decades (OECD, 2025). In response, international institutions such as the OECD and the European Union have developed classification frameworks and strategies aimed at addressing depopulation and promoting territorial development, with particular emphasis on infrastructure, access to services, and economic diversification (OECD, 2025; Gouaderès, 2024).

Within this policy and territorial context, one of the main barriers to rural development is the limited availability of infrastructure, particularly telecommunications infrastructure, which constrains entrepreneurial activity and SME development (Orduña & Sabater, 2022). Adequate telecommunications network coverage not only improves access to essential services such as healthcare and education but also supports the diversification of economic activities and enhances business opportunities (López-Taravilla et al., 2024).

Ultimately, depopulation affects not only the social fabric of rural areas but also their economic development by limiting access to key resources required for business activity. In this regard, the availability of telecommunications infrastructure becomes a critical factor, as it directly influences firms' capacity to operate, innovate, and compete in these environments. Against this backdrop, it is essential to analyze how access to telecommunications infrastructure, particularly digital connectivity, affects firms' economic performance in depopulated rural areas, given its role in shaping access to key external resources and business opportunities.

2.2. Digitalization, Connectivity, and Business Performance in Rural Environments

Industry has undergone several transformations throughout history, evolving from the era of the steam engine (Industry 1.0), through the introduction of electric power (Industry 2.0) and the emergence of electronics and information technology (Industry 3.0), to the current integration of intelligent digital technologies associated with Industry 4.0 (Gupta et al., 2021). In this context, digitalization, defined by Westreicher (2021) as "the process through which certain operations can begin to be carried out through digital means, such as computers or smartphones, usually with the help of an internet connection," enables the implementation of new digital technologies in business operations, transforming the way firms operate (Álvarez, 2022) and constituting the foundation of the broader technological transition process.

In the business sphere, digitalization refers to the adoption of new technologies that drive changes and improvements in organizational processes, business models, and customer relationships (Bag et al., 2021). Among the main objectives firms pursue through digitalization are improving productivity, increasing efficiency and competitiveness, reducing costs and lead times, and strengthening connections with consumers through process automation and digital transformation (Gupta et al., 2021). Technologies commonly associated with business digitalization include email, e-commerce platforms, websites, and social networks (Cheney, 2015), as well as more advanced technologies such as virtual private networks (VPNs), cloud computing, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) (Frank et al., 2019). The integration of these advanced technological tools positively influences organizational performance by facilitating the transition toward more efficient business models (Lara-Pérez et al., 2026).

The development of telecommunications infrastructure can promote industrial modernization and job creation, thereby constituting a key factor in rural development (Chao et al., 2021). In this context, digital transformation has been defined as "the process focused on optimizing business performance through the implementation of significant changes supported by the combination of information systems, telecommunications, and connectivity" and, more comprehensively, as "a process in which digital technologies create disruptions triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process" (Vial, 2019, p. 118). According to Goldfarb and Tucker (2019), the implementation of these technologies can help firms reduce costs across various business functions, including search, service, monitoring, and verification, thereby improving the balance between income and expenditure (Yang, 2023).

Today, firms are increasingly deploying emerging digital technologies, such as internet connectivity, big data analytics, and artificial intelligence, to improve business performance (Frank et al., 2019). These technologies rely heavily on the availability of adequate telecommunications infrastructure. In addition to optimizing business operations, they create development opportunities in rural areas, thereby supporting business growth and, ultimately, population stabilization. Within this framework, connectivity constitutes a key enabler of digital transformation in SMEs by supporting technologies such as the Internet of Things (IoT), which automate tasks and improve operational efficiency (Alabdali et al., 2023). Although different forms of access to high-speed internet, including fixed broadband, 4G/5G mobile networks, satellite services, and Wi-Fi, have expanded connectivity options (ECLAC, 2021; International Telecommunication Union, 2022), connectivity gaps in rural areas, associated with geographical and infrastructure constraints, continue to hinder the deployment of technologies that facilitate digitalization and innovation in SMEs (Paschen et al., 2019; Gupta et al., 2021).

In addition to enabling communication between individuals, connectivity facilitates the creation of intelligent environments through the interconnection of devices, data collection, real-time information processing, and the application of artificial intelligence across diverse contexts (Fourati et al., 2022). For example, digital platforms can facilitate information exchange, reduce costs, and enable transactions among different stakeholder groups (Nocke et al., 2007; Xue et al., 2020). They can also support job searching, increase business efficiency, foster innovation and entrepreneurship, and improve communication among stakeholders, thereby helping management make better-informed decisions (Hao & Ji, 2023).

The implementation of these technologies underscores the importance of the infrastructure that enables internet connectivity. To achieve the productivity and efficiency gains associated with digitalization, firms require reliable network coverage capable of supporting stable connectivity among the different actors involved. This enables SMEs to exchange information more rapidly while also enhancing their capacity for innovation and competitiveness (Bag et al., 2021). Connectivity can also strengthen relationships with suppliers and customers, automate management processes, support the adoption of innovative technologies that generate competitive advantages, and facilitate expansion into new markets (Bag et al., 2021). Likewise, the modernization of business models enables SMEs to optimize processes, reduce costs (Gupta et al., 2021), improve relationships with stakeholders, expand into new markets, and enhance competitiveness (Bag et al., 2021). In this regard, previous studies have shown that access to network coverage positively affects the profitability and efficiency of family SMEs, highlighting its contribution to sustained business performance (López-Taravilla et al., 2024).

In this context, data becomes a strategic resource for analytical processes. The concept of big data refers to large, diverse, and rapidly generated datasets that exceed traditional processing capabilities and therefore require specialized analytical technologies (Ghasemaghaei & Calic, 2020; Tykheev, 2018). The analysis of these datasets, commonly referred to as Big Data Analytics (BDA), supports managerial decision-making and transforms planning, marketing, distribution, and supply chain management, with direct effects on sales performance, cost reduction, and customer understanding (Gupta et al., 2021; Choi et al., 2018; Brinch et al., 2018; Kamble & Gunasekaran, 2020). In SMEs, these capabilities facilitate more informed decision-making and more precise market segmentation (Ahlemeyer-Stubbe & Coleman, 2014; Shirazi & Mohammadi, 2019). Artificial intelligence (AI) further expands this potential through algorithms capable of executing rules, learning from data, and optimizing processes, thereby strengthening product innovation and facilitating market entry (Gupta et al., 2021; Bag et al., 2021; Anshari et al., 2018; Jabbar et al., 2019; Ahlemeyer-Stubbe & Coleman, 2014). Beyond internal management processes, AI can also optimize digital connectivity infrastructure by integrating terrestrial, aerial, and space-based networks in contexts where deployment costs are high (Fourati et al., 2022; Handforth, 2019), such as rural areas. However, the development of these capabilities requires tangible resources and specialized human capital, posing a particular challenge in rural environments where access to advanced training remains limited (Bag et al., 2021; Pérez López, 2023).

Despite the advantages highlighted above, the adoption of these technologies also presents significant challenges. From an economic perspective, SMEs face multiple pressures from different stakeholders when adopting digital technologies, requiring them to adapt their resources and capabilities accordingly (Bag et al., 2021). The implementation of these technologies requires SMEs to make substantial investments, including the acquisition of intangible assets such as software and databases, employee training and professional development, the establishment of R&D departments, and the adaptation of corporate IT systems, among others. The scale and nature of these investments vary according to the characteristics and strategic orientation of each organization (López-Taravilla et al., 2024).

Indeed, firm performance is intrinsically linked to the surrounding environment. As discussed earlier, a firm's success may depend on its ability to gain competitive advantages and improve efficiency by optimizing processes through the adoption of contemporary digital technologies. Consequently, the implementation of digitalization in SMEs requires adequate investment in new technologies. However, such investment is only likely to be effective when accompanied by telecommunications infrastructure capable of ensuring adequate connectivity. In depopulated rural environments, where access to resources such as telecommunications infrastructure is limited, firm performance is strongly conditioned by the resources available within the surrounding territory (Backman & Palmberg, 2015; Dicken & Malmberg, 2011; Pfeffer & Salancik, 1978). In response to this structural vulnerability, Morris et al. (2022) argue that digital connectivity becomes a critical factor in the resilience of rural SMEs, functioning as a mechanism for survival in the face of territorial structural crises.

It is at this point that digital connectivity becomes particularly important. Technological innovation emerges as a key factor in moderating the adverse effects of rural depopulation, while adequate telecommunications infrastructure supports economic diversification and the maintenance of international competitiveness. However, the expansion of connectivity is itself conditioned by geographical and regional economic factors, thereby contributing to the persistence of the digital divide.

In sum, access to adequate telecommunications infrastructure is essential for both communities and businesses. Accordingly, public institutions at the regional, national, and European levels provide a range of resources aimed at improving such access. If telecommunications infrastructure were as accessible in rural areas as in urban areas, rural SMEs would be better equipped to address and adapt to current challenges, thereby strengthening their development and helping prevent the abandonment of rural areas.

Within this framework, it is important to examine whether access to high-speed internet networks is associated with improved SME performance in rural and depopulated areas. The existing literature identifies several mechanisms through which digital connectivity may enhance firm performance. In particular, broadband and advanced telecommunications infrastructures can reduce transaction costs, improve access to markets, facilitate coordination with suppliers and customers, and increase operational efficiency (Goldfarb & Tucker, 2019; Vial, 2019; Gupta et al., 2021).

In addition, improved connectivity can mitigate geographical constraints, enabling firms located in less developed areas to participate more effectively in broader economic networks and strengthen their competitive position. These factors may contribute to higher productivity and, ultimately, improved financial performance.

Taken together, these mechanisms suggest that access to broadband infrastructure improves firms' economic outcomes by enhancing efficiency, reducing operating costs, and expanding market opportunities. This is particularly relevant in rural and depopulated environments, where firms face significant structural constraints.

Based on the foregoing literature review, the following research hypothesis is proposed:

H1: Improved access to broadband network coverage in depopulated rural areas is positively associated with changes in the performance of SMEs located in those areas.

3. Methodology

3.1. 5G Technology and the Geographical Context of Castilla-La Mancha

This study is based on a quantitative analysis examining the relationship between access to telecommunications infrastructure, specifically network coverage, and SME performance in depopulated rural areas. The study tests whether greater mobile broadband coverage, particularly through 5G technology, positively affects the performance of SMEs located in depopulated rural environments.

5G network coverage was selected as an indicator of access to advanced telecommunications infrastructure due to its capacity to act as a catalyst for digital transformation (Olokundun et al., 2022), making it particularly suitable for the purposes of this analysis. As the fifth generation of mobile networks, 5G represents a substantial advance over previous technologies such as 3G and 4G by offering significantly higher transmission speeds, ultra-low latency enabling near-instantaneous responses, and greater capacity for simultaneous connections. These characteristics make it a reliable indicator of the level of digitalization and technological modernization within a territory (Attaran, 2023). In this regard, Olokundun et al. (2022) emphasize that 5G is essential for digital innovation in SMEs because it enables the adoption of new business models that would not be feasible without this infrastructure. Likewise, 5G not only improves connectivity but also facilitates the deployment of emerging technologies such as the Internet of Things (IoT), real-time artificial intelligence, big data analytics, and industrial automation systems, all of which require fast and stable networks that 5G is specifically designed to support (Sun, 2025). Consequently, the presence or absence of 5G coverage may have a tangible impact on the capacity of SMEs to digitalize and remain competitive.

Furthermore, 5G is currently the most advanced mobile telecommunications technology available in Castilla-La Mancha, the region selected for this study due to its pronounced depopulation. Castilla-La Mancha comprises 919 municipalities, 68% of which had a population density below 12.5 inhabitants/km² in 2025, making it the third least densely populated autonomous community in Spain. This situation is further exacerbated by the regional digital divide, reinforcing the suitability of Castilla-La Mancha as the geographical context for the study. Although the region has made significant progress in the deployment of fiber-to-the-home (FTTH) broadband infrastructure, and technologies such as 3G, 4G, and satellite connections provide coverage across almost the entire territory, important limitations persist in access to next-generation networks such as 5G, particularly in rural areas characterized by higher levels of depopulation (Coverage CLM, 2024; Bilib, 2025).

In this context, the Government of Castilla-La Mancha enacted Law 2/2021 on Measures Against Depopulation and for Rural Development, which explicitly recognizes the role of digital connectivity in guaranteeing equal opportunities and promoting economic activity in municipalities classified according to their degree of depopulation (JCCM, 2025; Aguilera Maldonado et al., 2024). The law also establishes specific instruments to promote broadband infrastructure and ICT services in areas affected by depopulation and market deficiencies, thereby aligning regional objectives with European strategies and funding mechanisms (RTVE, 2021; Ruiz Pulpón & Ruiz González, 2021). From a business economics perspective, this regulatory framework provides an opportunity to analyze how the presence or absence of connectivity shapes firms' interaction with the resources available within their environment, as proposed by Resource Dependence Theory (Pfeffer & Salancik, 1978), and ultimately how these conditions influence SME performance (Dicken & Malmberg, 2011; López-Taravilla et al., 2024).

This territorial inequality is central to understanding how the availability of connectivity influences business performance indicators, making Castilla-La Mancha a representative case for evaluating the extent to which connectivity policies can act as a driver of regional development.

3.2. Study Sample

The study adopts a quantitative approach based on data collected from multiple secondary sources. Specifically, the SABI database (Bureau van Dijk) was used to obtain financial, structural, and geographical information on the firms included in the sample. The initial sample consisted of 69,446 firms located in Castilla-La Mancha, selected as limited liability companies that met the European Union's definition of an SME.[1] Firms with missing data were excluded because incomplete observations would have prevented their inclusion in the empirical analysis. Data on broadband coverage speeds were obtained from the State Secretariat for Telecommunications and Digital Infrastructure (SETELECO, 2025).[2] Information on the classification of municipalities in Castilla-La Mancha according to their degree of depopulation was obtained from the Spanish Tax Agency (AEAT, 2025).[3]

From the initial sample, only firms located in municipalities classified as being at risk of depopulation or experiencing intense or extreme depopulation were retained, consistent with the study's focus on the relationship between telecommunications infrastructure and SME performance in depopulated rural areas. This selection process resulted in a final sample of 3,498 firms.

Table 1. *Study Design Summary*

Study population	SMEs in Castilla-La Mancha located in depopulated rural areas
Geographical scope	Castilla-La Mancha, Spain
Methodology	Secondary data analysis — SABI, AEAT, and SETELECO databases
Sample size	3,498 firms
Sampling error*	±5%
Significance level	95%
Sampling	Convenience sampling
Data retrieval date	February 2025

3.3. Study Variables

The objective of this study is to examine whether SME performance is affected by access to 5G broadband network coverage, differentiating the effects according to the level of depopulation in the municipality where each firm is located.

Dependent variable: Medium-term ROA variation

The dependent variable is the performance of SMEs located in depopulated rural areas in Castilla-La Mancha. Financial data were obtained from the SABI database. Firm performance is proxied by ROA (return on assets), a measure consistent with previous research using ROA as an indicator of business performance in response to external factors (Backman & Palmberg, 2015; López-Taravilla et al., 2023, 2024; Sinitan & Socol, 2020). ROA is calculated as earnings before interest and taxes divided by the total assets of each firm included in the sample.

$$\mathrm{ROA} = \frac{\mathrm{EBIT}}{\mathrm{Total\ Assets}} \qquad [1]$$

Where:

ROA = return on assets

EBIT = earnings before interest and taxes

Medium-term changes in ROA are captured by calculating the growth rate over the period 2021–2023:

1 The definition of SMEs established by the European Union in Recommendation 2003/361/EC classifies enterprises according to their size. Micro-enterprises employ fewer than 10 persons and have an annual turnover or annual balance sheet total not exceeding €2 million. Small enterprises employ fewer than 50 persons and have an annual turnover or annual balance sheet total not exceeding €10 million. Medium-sized enterprises employ fewer than 250 persons and have an annual turnover not exceeding €50 million or an annual balance sheet total not exceeding €43 million.

2 Coverage data on broadband speeds provided by the State Secretariat for Telecommunications and Digital Infrastructure (SETELECO). The coverage information portal is jointly maintained by SETELECO and the State Secretariat for Digitalization and Artificial Intelligence. See: avance.digital.gob.es

3 Municipal depopulation classification data for Castilla-La Mancha obtained from the Spanish Tax Agency (*Agencia Estatal de Administración Tributaria*, AEAT) in accordance with the official municipal classification established under Law 2/2021 on Measures Against Depopulation and for Rural Development.

$$\Delta ROA_{21\text{-}23} = \frac{ROA_{23} - ROA_{21}}{ROA_{21}} \quad [2]$$

Where:

ΔROA_{21-23} = change in ROA

ROA_{23} = return on assets in 2023

ROA_{21} = return on assets in 2021

Using the rate of change in ROA, rather than its absolute level, reflects the need to examine the evolution of SME performance over time in line with the rollout of 5G networks in Castilla-La Mancha. This approach makes it possible to assess whether improvements in connectivity, treated as an external resource, significantly influence firms' economic performance in depopulated areas rather than merely reflecting their position at a specific point in time.

Explanatory variable: Variation in 5G coverage

Data on 5G network coverage were used as the explanatory variable, measured through access speeds under maximum download conditions and expressed as the percentage of households covered in each municipality (López-Taravilla et al., 2024). This measure reflects not only the availability of telecommunications infrastructure but also, following Olokundun et al. (2022), the minimum level of technological capacity required for rural SMEs to implement digital innovations that directly improve profitability. To capture the evolution of this infrastructure, the rate of change in 5G coverage between 2021 and 2023 was calculated in order to examine whether increased access to this network is associated with changes in firm performance.

$$\Delta C5G_{21\text{-}23} = \frac{C5G_{23} - C5G_{21}}{C5G_{21}} \quad [3]$$

Where:

$\Delta C5G_{21-23}$ = rate of change in 5G coverage

$C5G_{23}$ = 5G coverage in 2023

$C5G_{21}$ = 5G coverage in 2021

The selection of this variable is also informed by the provisions of Law 2/2021 of Castilla-La Mancha, through which the regional government seeks to guarantee access to ultra-fast broadband across the territory, thereby promoting economic productivity and social development. The regional government has likewise introduced a range of initiatives aimed at improving connectivity through the expansion of 5G coverage (Government of Castilla-La Mancha, 2022).

Categorical variable: Degree of depopulation

The official classification of municipalities in Castilla-La Mancha according to their degree of depopulation was used as the categorical variable (AEAT, 2025). For the purposes of this study, only municipalities classified as being at risk of depopulation or experiencing intense or extreme depopulation were retained. These categories were coded as shown in Table 2 to facilitate their inclusion in the empirical analysis.

Table 2. *Depopulation Categories*

Depopulation category	Coded value
At risk of depopulation	1
Intense depopulation	2
Extreme depopulation	3

Source: Authors' own elaboration.

Control variables: Firm age and firm size

To assess the impact of changes in network coverage on variations in firm performance, the study incorporates two control variables: firm age, measured as the difference between the observation year and the year of establishment, and firm size, measured as the natural logarithm of total assets and classified according to SME category (micro, small, or medium-sized). This approach is consistent with previous studies, including those by Backman and Palmberg (2015) and López-Taravilla et al. (2023, 2024).

Table 3. *Summary of Variables*

Variable	Measure	Description
ΔROA_{21-23}	$ROA_{21-23} = (ROA_{23} - ROA_{21}) / ROA_{21}$	Change in ROA from 2021 to 2023
$\Delta C5G_{21-23}$	$C5G_{21-23} = (C5G_{23} - C5G_{21}) / C5G_{21}$	Change in 5G network coverage from 2021 to 2023
Degree of depopulation	1 = At risk of depopulation; 2 = Intense depopulation; 3 = Extreme depopulation	Classification of municipalities according to their degree of depopulation
Size	Size = ln(Total $Assets_{23}$)	Firm size in 2023
Age	Age = 2023 − Year of establishment	Firm age in 2023

Source: Authors’ own elaboration.

4. Results

Statistical analyses were conducted using Stata software. Initially, descriptive statistics were calculated for all study variables. Subsequently, a bivariate correlation analysis was performed to identify potential relationships among the three key variables: the rate of change in return on assets (ΔROA_{21-23}), the rate of change in 5G network coverage ($\Delta C5G_{21-23}$), and the degree of depopulation. This approach made it possible to identify linear associations among these variables within the selected sample of firms and municipalities.

The empirical analysis is structured into three complementary stages and a robustness test. In the first model (M1), the effect of changes in 5G coverage on changes in ROA is estimated. In the second model (M2), the impact of depopulation on the same dependent variable is analyzed. In the third model (M3), the estimated variation in ROA explained by depopulation ($\Delta ROAest_{21-23}$) is constructed, and the role of 5G coverage in explaining this variable is evaluated.

Table 4 presents the descriptive statistics for the study variables: the rate of change in ROA (ΔROA_{21-23}), the rate of change in 5G coverage ($\Delta C5G_{21-23}$), and the degree of depopulation. The variable ΔROA_{21-23} shows a mean value of 1.183, whereas the median is negative (−0.376). This indicates that although some firms experienced substantial increases in performance, more than half of the SMEs recorded a decline in ROA between 2021 and 2023.

Table 4. *Descriptive Statistics*

Continuous variables	Mean	Median	SD	25th percentile	75th percentile
ΔROA_{21-23}	1.183	−0.376	67.377	−0.931	0.417
$\Delta C5G_{21-23}$	33.557	0.000	345.023	0.000	0.155
Size	5.851	5.816	1.334	4.930	6.730
Age	18.185	18	10.051	9	26
Categorical variable	***N***		**%**		
Degree of depopulation					
At risk of depopulation (1)	199		5.69		
Intense depopulation (2)	1,794		51.29		
Extreme depopulation (3)	1,505		43.02		

Source: Authors’ own elaboration.

Regarding $\Delta C5G_{21-23}$, the mean value is 33.557, whereas the median is 0. This indicates that growth in 5G coverage has been concentrated in a relatively small number of municipalities, while most experienced no variation, resulting in substantial dispersion (standard deviation = 345.023).

With respect to the degree of depopulation, most of the SMEs included in the analysis are located in municipalities classified as experiencing intense depopulation (51.29%), followed by municipalities classified as experiencing extreme depopulation (43.02%). Municipalities classified as being at risk of depopulation account for only 5.69% of the sample.

In addition, a bivariate correlation analysis using Pearson's correlation coefficient was conducted to examine the relationships among the study variables. This coefficient ranges from −1 to 1 and indicates both the strength and direction of the linear relationship between variables, with positive and negative values reflecting the direction of the association.

Table 5. *Correlation Matrix*

	1	2	3	4	5
1. ΔROA_{21-23}					
2. $\Delta C5G_{21-23}$	.195***				
3. Size	−.068***	−.036**			
4. Age	.005	.022	.262***		
5. Degree of depopulation	−.038**	−.184***	−.028*	.000	

Note. * $p < .10$. ** $p < .05$. *** $p < .01$. All tests two-tailed.

Source: Authors' own elaboration

Table 5 shows a positive and statistically significant correlation between changes in 5G coverage and changes in SME ROA ($r = .195$, $p < .01$). This result suggests that increases in 5G coverage across municipalities tend to be associated with improvements in the performance of SMEs located in those areas, supporting the view that advanced telecommunications infrastructure facilitates digitalization and competitiveness.

The depopulation variable is also statistically significant ($p < .05$) in relation to changes in SME ROA. However, unlike 5G coverage, this relationship is negative ($r = -.038$). This finding suggests that higher levels of depopulation are associated with smaller improvements in business performance, indicating that SMEs located in more depopulated areas tend to experience lower growth or even declines in performance.

Furthermore, the relationship between depopulation and access to 5G coverage was also examined, revealing a negative and statistically significant association ($r = -.184$, $p < .01$). This finding suggests that higher levels of depopulation tend to be associated with lower levels of telecommunications infrastructure coverage. This pattern is consistent with well-established territorial dynamics, as population decline and low population density tend to discourage investment in telecommunications infrastructure. In this regard, the results reinforce the need for public policies aimed at promoting investment in connectivity in depopulated areas in order to prevent the digital divide from becoming a structural source of territorial and business inequality.

In addition, a mean comparison analysis was conducted across the three depopulation categories. The ANOVA results reveal statistically significant differences among the categories (see Table 6), corroborating the correlation findings reported above for both ROA variation and 5G coverage. With respect to ΔROA_{21-23}, firms located in municipalities classified as being at risk of depopulation exhibited substantially larger mean changes (19.089) than those located in areas experiencing intense depopulation (0.153) or extreme depopulation (0.043). The corresponding F-statistic ($F = 7.48$, $p < .001$) confirms that these differences are statistically significant, suggesting that the degree of depopulation within a territory is associated with distinct SME performance trajectories over time.

A similar, but even more pronounced, pattern emerges for $\Delta C5G_{21-23}$. Firms located in municipalities classified as being at risk of depopulation exhibited a mean change of 477.779, substantially exceeding the values observed in areas experiencing intense depopulation (7.889) and extreme depopulation (5.417). The corresponding F-statistic ($F = 194.24$, $p < .001$) confirms that these differences are highly statistically significant. This result indicates that changes in 5G coverage vary markedly across depopulation categories, with firms located in less depopulated areas experiencing substantially greater increases in connectivity infrastructure.

Table 6. *Mean Comparison of Study Variables by Degree of Depopulation*

	At risk of depopulation (1)	Intense depopulation (2)	Extreme depopulation (3)	*F*
ΔROA_{21-23}	19.089	0.153	0.043	7.48***
$\Delta C5G_{21-23}$	477.779	7.889	5.417	194.24***
Size	5.862	5.891	5.801	1.86
Age	2.819	2.682	2.722	4.17**

Note. Values represent group means. ** $p < .05$. *** $p < .01$.

Source: Authors' own elaboration.

Given that access to 5G network coverage and territorial depopulation are significantly correlated, these variables were not included jointly in the baseline models. To address this issue, the empirical analysis was conducted sequentially using a set of ordinary least squares (OLS) regression models. First, the direct effect of access to 5G networks on ROA variation was estimated. Second, the impact of rural depopulation on the same dependent variable was assessed. Finally, the analysis examined whether access to 5G networks explains the portion of ROA variation associated with depopulation.

Table 7 reports the results of the OLS models analyzing the relationship between changes in ROA and 5G coverage across different levels of depopulation.

Table 7. *OLS Regression Results: $\Delta ROA_{21–23}$ and $\Delta C5G_{21–23}$ by Degree of Depopulation (Models 1–3)*

	Model 1	**Model 2**	**Model 3.1**	**Model 3.2**
Dependent variable	$\Delta ROA_{21–23}$	$\Delta ROA_{21–23}$	$\Delta ROA_{21–23}$	$ROAest_{21–23}$
Independent variables				
$\Delta C5G_{21–23}$	0.037***			0.001***
	(0.003)			(0.000)
Degree of depopulation		−4.579**	−4.339**	
		(1.927)	(1.931)	
Controls				
$Size_{23}$	−3.307***	−3.807***		0.074**
	(0.868)	(0.883)		(0.033)
Age_{23}	1.758	2.434		−0.052
	(1.694)	(1.724)		(0.065)
Prob > *F*	.000	.000	.025	.000
R^2	.042	.007	.001	.035
Adj. R^2	.041	.006	.001	.034
N (firms)	3,498	3,498	3,498	3,498
N (observations)	3,498	3,498	3,498	3,498

Note. Results are based on a sample of 3,498 firms located in depopulated rural municipalities in Castilla-La Mancha, Spain, for the period 2021–2023. Standard errors are reported in parentheses. * $p < .10$. ** $p < .05$. *** $p < .01$.

Source: Authors' own elaboration.

Model 1. The Effect of Changes in 5G Coverage on Changes in ROA, Controlling for Firm Characteristics

In Model 1, an OLS regression model is estimated in which variation in firm ROA is explained by variation in access to 5G networks within the municipality where the firm is located, while controlling for firm size and firm age.

$$\Delta \mathrm{ROA}_{21-23} = \beta_0 + \beta_1 \Delta \mathrm{C5G}_{21-23} + \beta_2 \mathrm{Logsize}_{23} + \beta_3 \mathrm{Logage}_{23} \quad [4]$$

The results show a positive and statistically significant effect of 5G coverage on ROA variation (β = 0.03755, $p < .001$). This finding suggests that increases in 5G coverage are associated with improvements in firm performance. Although the magnitude of the relationship is modest, the coefficient remains statistically significant, supporting the hypothesis that access to 5G telecommunications infrastructure may positively influence SME performance.

Model 2. Effect of Depopulation on Changes in ROA

In Model 2, an OLS regression model is estimated to analyze the relationship between territorial depopulation and variation in ROA, while controlling for firm size and firm age.

$$\Delta \mathrm{ROA}_{21-23} = \beta_0 + \beta_1 \mathrm{DESPOCAT}_{23} + \beta_2 \mathrm{Logsize}_{23} + \beta_3 \mathrm{Logage}_{23} \quad [5]$$

The results show a negative and statistically significant relationship between territorial depopulation and ROA variation (β = −4.579, $p = .018$). After controlling for firm size and age to account for structural differences among firms, higher levels of depopulation are associated with smaller improvements in firm performance.

Model 3. 5G Access and the Adverse Effect of Depopulation on Firm Performance

To examine whether the deployment of 5G networks mitigates the adverse effect of depopulation on firm performance, the analysis proceeds in two stages, resulting in two submodels: Model 3.1 and Model 3.2.

Model 3.1. Estimation of the ROA Component Explained by Depopulation

In the first stage, an OLS regression model is estimated in which variation in ROA is explained by the degree of depopulation (DESPOCAT, treated as a categorical variable). This model isolates the proportion of ROA variation associated with demographic conditions.

$$\Delta ROA_{21-23} = \beta_0 + \beta_1 DESPOCAT_{23} + \varepsilon_{23} \quad [6]$$

The estimated depopulation coefficient is negative and statistically significant, indicating that higher levels of depopulation are associated with smaller improvements in firm performance. Two key elements are derived from this model:

- **Residuals (ε_{23}):** These represent the portion of ROA variation not explained by depopulation, reflecting firm-specific internal or environmental characteristics that cannot always be directly measured. Residual analysis also helps assess model specification, detect potential omitted-variable patterns or specification errors, and thereby strengthen the robustness of the conclusions (García et al., 2019; Wodtke et al., 2020; Segarra-Blasco et al., 2025).

- **Estimated variable ($\Delta ROAest_{21-23}$):** Defined as the actual change in ROA minus the residuals, this variable captures the proportion of ROA variation explained by depopulation. This step is essential because it isolates the demographic effect on profitability and subsequently makes it possible to assess whether digital connectivity can mitigate this effect.

Model 3.2. Evaluation of the Role of 5G in Mitigating the Effect of Depopulation

In the second stage, $\Delta ROAest_{21-23}$ is used as the dependent variable in a new OLS regression model in which the main explanatory variable is the change in 5G coverage ($\Delta C5G_{21-23}$), together with firm-level control variables (firm size and firm age). This model focuses exclusively on depopulated areas without directly including the level of depopulation as an explanatory variable, since the objective is to assess whether access to 5G networks independently contributes to explaining changes in ROA. This approach tests whether the deployment of high-speed telecommunications infrastructure can act as a mitigating factor against the adverse effects of depopulation on firm performance.

$$\Delta ROAest_{21-23} = \beta_0 + \beta_1 \Delta C5G_{21-23} + \beta_2 Logsize_{23} + \beta_3 Logage_{23} + \varepsilon_{23} \quad [7]$$

The results show that variation in 5G network coverage has a positive and highly statistically significant effect on the proportion of ROA variation associated with depopulation ($\beta = 0.00138$, $p < .001$). This finding suggests that higher levels of 5G coverage are associated with increases in the component of ROA variation explained by depopulation.

Robustness Analysis

To further assess the robustness of the main findings, a fourth model was estimated to evaluate whether the effect of 5G expansion on firm performance differs across territories with varying levels of depopulation. An OLS regression model was estimated in which the dependent variable is the change in ROA (ΔROA_{21-23}), and the main explanatory variable is the mean-centered change in 5G coverage ($\Delta C5Gc_{21-23}$, hereafter $\Delta C5Gc$), which facilitates interpretation of the main effects in the presence of an interaction term (Hayes, 2013).

The model additionally includes a depopulation dummy variable (DESPOCATbi), coded as 0 for municipalities at risk of depopulation and 1 for municipalities experiencing intense or extreme depopulation, together with the interaction term between the depopulation dummy and the mean-centered variation in 5G coverage ($\Delta C5Gc \times DESPOCATbi$). This specification makes it possible to examine whether the effect of 5G on ΔROA differs across territories according to the intensity of depopulation.

Mean-centering ΔC5G (i.e., constructing $\Delta C5Gc = \Delta C5G - \Delta C5\bar{G}$) does not alter the overall model fit or the statistical significance of the interaction term. Rather, it renders the main-effect coefficients interpretable at the mean level of 5G coverage and reduces collinearity between the predictors and the interaction term (Hayes, 2013). In the context of this study, this procedure clarifies the estimated effect at average levels of 5G coverage and how the slope varies across depopulation categories.

$$\Delta ROA_{21-23} = \beta_0 + \beta_1 \Delta C5Gc_{21-23} + \beta_2 DESPOCATbi_{23} + \beta_3 (\Delta C5Gc \times DESPOCATbi)23 + \beta_4 Logsize23 + \beta_5 Logage_{23} \quad [8]$$

Table 8. *Robustness Analysis: Moderating Effect of Depopulation Intensity on the Relationship Between 5G Coverage and Firm Performance (Model 4)*

	Robustness analysis
Dependent variable	ΔROA_{21-23}
Independent variables	
$\Delta C5Gc_{21-23}$	0.042***
	(0.004)
DESPOCATbi	0.052
	(5.081)
Interaction	
$\Delta C5Gc_{21-23} \times$ DESPOCATbi	−0.041***
	(0.010)
Controls	
$Size_{23}$	−3.212***
	(0.866)
Age_{23}	1.836
	(1.692)
Prob > *F*	.000
R^2	.046
Adj. R^2	.045
N (firms)	3,498
N (observations)	3,498

Note. Results are based on a sample of 3,498 firms located in depopulated rural municipalities in Castilla-La Mancha, Spain, for the period 2021–2023. Standard errors are reported in parentheses. * $p < .10$. ** $p < .05$. *** $p < .01$.

Source: Authors' own elaboration.

The results indicate that the effect of increased 5G coverage on ROA is positive and statistically significant in municipalities classified as being at risk of depopulation (DESPOCATbi = 0) (β = 0.04236, $p < .001$). However, the interaction between ΔC5Gc and the condition of intense or extreme depopulation is negative and statistically significant (β = −0.041, $p < .001$), confirming that the effect of 5G is not homogeneous but varies according to the intensity of depopulation. This finding implies that, on average, increases in 5G coverage are associated with smaller improvements in ROA in areas experiencing intense or extreme depopulation.

5. Discussion and Conclusions

The literature review has shown that the adoption of new technologies can influence SME performance by improving internal processes (Frank et al., 2019), reducing costs, and increasing efficiency (ECLAC, 2021). In addition, the integration of advanced technological tools facilitates the transition toward more efficient business models (Lara-Pérez et al., 2026). However, for this potential to materialize in depopulated rural areas, firms' internal resources and strategic willingness alone are insufficient; adequate telecommunications infrastructure is also required.

In depopulated rural areas, achieving this objective is more difficult, as inadequate infrastructure and the digital divide continue to constitute major barriers to the deployment of these technologies (Paschen et al., 2019; Gupta et al., 2021). These limitations are compounded by low population density and high logistics costs, which already represent significant challenges for SME performance (Magdalena, 2025). From the perspective of Resource Dependence Theory (Pfeffer & Salancik, 1978), when a territory does not provide the necessary external resources—in this case, adequate telecommunications infrastructure—firms' capacity to compete is diminished. In this context, the availability of such infrastructure becomes a fundamental requirement for rural SMEs to survive and adapt to the challenges of their environment (Morris et al., 2022).

It is within this territorial framework, characterized by specific limitations and structural challenges, that the results of this study should be interpreted. The findings indicate that SME performance is positively associated with access to 5G network coverage, reinforcing the view that telecommunications infrastructure functions as a key enabling factor for business activity. Previous studies have likewise shown that connectivity facilitates improvements in efficiency and profitability (Olokundun et al., 2022; López-Taravilla et al., 2024; Bag et al., 2021), and the present findings provide additional empirical support for these arguments.

First, the analysis confirmed a positive effect of 5G coverage on firm performance, a result consistent with previous studies emphasizing the importance of telecommunications infrastructure as a facilitator of business development. For example, Olokundun et al. (2022) argue that the defining characteristics of 5G, particularly its high speed and low latency, are fundamental to digital innovation in SMEs, contributing to improvements in both efficiency and profitability. Similarly, López-Taravilla et al. (2024) and Bag et al. (2021) have shown that strong connectivity enables firms to exchange information more rapidly, thereby fostering innovation and competitiveness, while access to high-quality networks positively affects the sustained profitability and efficiency of family businesses. Taken together, these studies support the hypothesis that investment in telecommunications infrastructure such as 5G constitutes a key factor in improving business profitability.

Nevertheless, this positive effect must be interpreted in light of the structural constraints characterizing rural contexts. As Bag et al. (2021) point out, firms' adoption of digital connectivity depends on the availability of adequate supporting infrastructure within the territory. In depopulated areas, where demand is limited and implementation costs are high, investment in technologies such as 5G is less likely to occur, which in turn restricts these territories' access to the benefits of digitalization. This structural constraint reinforces the need for targeted public policies aimed at reducing the digital divide and ensuring that the benefits of 5G are not concentrated exclusively in urban areas.

At the same time, the negative relationship between depopulation and profitability suggests that SMEs located in more depopulated areas tend to experience weaker performance growth. This may result from reduced local demand, shortages of skilled labor, and lower attractiveness for new investment, factors that in turn intensify the depopulation process. As Magdalena (2025) notes, conditions specific to rural environments, such as low population density and high logistics costs, exert persistent pressure on the performance of local businesses, thereby limiting their capacity for economic growth. This dynamic generates a vicious cycle of depopulation and economic decline in which the lack of business opportunities contributes to outward migration, while population decline further reduces economic activity and the availability of essential resources for firms. This interpretation is consistent with the findings of Becerra and Pérez González (2025), who argue that depopulation constitutes a major obstacle to economic development and emphasize the need for more integrated policies that promote economic opportunities, services, and infrastructure, improve quality of life, and thereby support the establishment and retention of SMEs in depopulated areas.

More importantly, when both factors are considered simultaneously, the analysis indicates that access to 5G coverage mitigates the adverse effects of depopulation, partially compensating for the disadvantages associated with operating in depopulated areas. Firms located in depopulated territories with greater access to 5G networks appear better able to counteract part of the negative impact of depopulation on profitability. This finding is consistent with Morris et al. (2022), who argue that digital connectivity becomes a critical factor in the resilience of rural SMEs, functioning as a survival mechanism. Furthermore, Olokundun et al. (2022) provide a theoretical explanation for how 5G, through digital innovation, can improve business efficiency and profitability, thereby helping to explain this mitigating effect.

However, this mitigating role is not unconditional. In depopulated areas, where demand is limited and infrastructure deployment costs are high, investment in technologies such as 5G remains constrained, thereby restricting firms' ability to fully benefit from digitalization. This finding highlights the importance of complementing telecommunications infrastructure deployment with broader territorial policies aimed at addressing existing structural inequalities.

In addition, the robustness analysis introduces an important nuance. In areas experiencing intense or extreme depopulation, the positive association between 5G coverage and firm performance is significantly weaker. This evidence reinforces the view that severe depopulation constrains the capacity of 5G deployment to translate into improvements in firm performance. This phenomenon is consistent with the concept of complementarity, according to which 5G connectivity typically requires the presence of additional resources and capabilities in order to generate performance improvements. These include organizational and digital capabilities, human capital, business density, and provider networks, particularly in territories affected by more severe depopulation. In this regard, Resource Dependence Theory (Pfeffer & Salancik, 1978) becomes especially relevant, as it suggests that the scarcity of complementary external resources in highly depopulated areas restricts firms' ability to fully leverage 5G infrastructure, thereby reducing its positive impact.

Overall, the study shows that although depopulation negatively affects SME performance, 5G connectivity helps mitigate this impact and thereby contributes to sustaining economic activity within the region. The digital divide therefore represents not only inequality in access to telecommunications infrastructure, but also a structural factor that intensifies territorial economic inequality.

From an international perspective, these findings offer relevant insights for rural areas facing similar challenges, demonstrating that the deployment of telecommunications infrastructure such as 5G should be regarded as a priority not only for territorial equality but also for economic efficiency. For policymakers, the results suggest that supporting the deployment of telecommunications infrastructure in depopulated rural areas should be viewed not as a cost, but as an investment in economic resilience capable of mitigating the effects of depopulation and promoting regional socioeconomic development. However, the evidence also indicates that infrastructure alone is insufficient; it must be accompanied by training initiatives, support for entrepreneurship, and programs that encourage the effective adoption of digital technologies. For the business sector, the study highlights that the incorporation of 5G-related digital technologies—such as AI, big data analytics, and the Internet of Things (IoT)—can help offset some of the limitations inherent in operating within depopulated environments.

Despite the robustness of the analysis, this study is not without limitations. The period examined (2021–2023) and the selected geographical area constrain the observation of long-term effects. Furthermore, measuring connectivity solely through 5G coverage excludes other relevant dimensions, such as the extent to which employees actually use these technologies and the level of training required to use them effectively.

These limitations open several avenues for future research, including comparative studies across regions to assess whether the mitigating effect of 5G on depopulation varies according to different regulatory frameworks and levels of technological development; longitudinal analyses of technology adoption processes; and the incorporation of qualitative approaches to better understand how connectivity and digitalization influence business resilience and rural sustainability.

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