The influence of digital transformation and implementation barriers on innovation in Brazilian micro, small, and medium enterprises

La influencia de la transformación digital y la implementación de barreras en la innovación de las micro, pequeñas y medianas empresas brasileñas

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Abstract

This study aims to analyze the influence of digital transformation on innovation and the moderating role of barriers to digitalization in this relationship within Brazilian micro, small, and medium enterprises (MSMEs). The sample comprises 731 Brazilian MSMEs. The findings indicate that digital transformation, characterized by digitalization strategies and technology usage, has a positive and significant impact on innovation. Moreover, barriers to digitalization negatively and significantly affect the relationship between digital transformation and innovation, but this effect is observed only in medium-sized enterprises. This study contributes to strategic management practices by providing insights into the role of digital transformation in business innovation. Future research should investigate why barriers to digitalization do not consistently impact the relationship between digital transformation and innovation.

Keywords: digital transformation; digitalization strategies; technology usage; innovation; barriers; MSMEs
JEL Classification: C39; M10; M14; O31

Resumen

Este estudio tiene como objetivo analizar la influencia de la transformación digital en la innovación y el papel moderador de las barreras a la digitalización de las micro, pequeñas y medianas empresas (MIPYMES) brasileñas. La muestra comprende 731 MIPYMES brasileñas. Los resultados indican que la transformación digital, caracterizada por las estrategias de digitalización y el uso de la tecnología, tiene un impacto positivo y significativo en la innovación. Además, las barreras a la digitalización afectan negativa y significativamente a la relación entre transformación digital e innovación, pero este efecto sólo se observa en las medianas empresas. Este estudio contribuye a las prácticas de gestión estratégica al proporcionar información sobre el papel de la transformación digital en la innovación empresarial. Futuras investigaciones deberán indagar por qué las barreras a la digitalización no afectan de forma consistente a la relación entre transformación digital e innovación.

Palabras clave: transformación digital; estrategias de digitalización; uso de la tecnología; innovación; barreras; PYMEs
Clasificación JEL: C39; M10; M14; O31

1. Introduction

Digital transformation has emerged as a critical factor in the contemporary landscape of micro, small, and medium enterprises (MSMEs), which face inherent challenges to innovation, including resource constraints, competitive pressures, and complex innovation processes (Austin et al., 2021; Cichosz et al., 2020; OECD, 2020; Peillon & Dubruc, 2019).

Digital transformation is often perceived as a strategic business initiative focused on achieving financial outcomes, driving informed decision-making, and fostering changes in business models (Begnini et al., 2024). Strategies that aim to generate new processes, ideas, products, and services are particularly effective in creating value, especially in the context of technological advancements (Cennamo et al., 2023; Firmino et al., 2022; Furr & Shipilov, 2019). For instance, following the COVID-19 pandemic, many small and medium-sized enterprises adopted new technology usage strategies to enhance their business value (Mandviwalla & Flanagan, 2021), including expanding social networks, implementing telecommuting, utilizing digital banking, and engaging in e-commerce (FAEDPYME, 2022a).

Digital transformation involves developing strategies and employing technologies that fit the business innovation models of MSMEs. According to Castellar et al. (2021), successful business models and innovative technologies are those that target organizational strategies and align with strategic values. The adoption of information and communication technologies (ICTs) has positively influenced the economic growth of innovative countries within the OECD, highlighting the connection between innovation and digital technology use by individuals, businesses, and governments in developing European Union nations. This relationship boosts per capita GDP returns and enables MSMEs to strategically leverage ICTs (Gomes et al., 2022).

The use of big data tools, for example, has been shown to significantly impact both technological and market strategies, positively influencing the product innovation process (Pinochet et al., 2021). Similarly, the journey toward digital transformation requires a commitment to change, new ways of thinking, and the development of new strategies (Girardi, 2023). Furr and Shipilov (2019) suggest that each business segment can tailor its digital approach to its specific needs, thereby reducing the risk of disruption. To achieve growth in the digital environment, businesses must meet the needs of digital customers and redefine their value propositions (Subramaniam, 2022a).

Some studies have identified digital insecurity (Mohammadi, 2016; Papadopoulos et al., 2020) and a lack of financial resources (Austin et al., 2021; Cichosz et al., 2020; OECD, 2020; J. A. Pereira & Bernardo, 2016) as additional barriers to digital transformation. Resistance to change is another significant challenge, occurring among both employees, who may fear being replaced by technology, and managers, who often lack the technical expertise needed to effectively lead digital transformation efforts (Cichosz et al., 2020; Fountaine et al., 2019; Horváth & Szabó, 2019).

The use of technologies and digital strategies by MSMEs requires resources and competencies that reflect dynamic capabilities (Teece et al., 1997). As MSMEs operate in a dynamic environment, they must continually renew their competencies to remain competitive (Eisenhardt & Martin, 2000). Human and investment resources are influenced by past decisions and, when combined with the dynamism of the environment, establish new requirements for action in response to emerging digital business models. Dynamic capabilities are structured around three pillars: processes (routines or patterns of standard practices and learning), positions (assets, governance structures, customer base, and external relationships with suppliers and partners), and trajectory (the history of decisions and the identification of technological and market opportunities) (Meirelles & Camargo, 2014).

Dynamic capabilities are associated with digital transformation in the operating environment of MSMEs through the introduction of routine mechanisms that enable the reorganization of capabilities (Winter, 2003). In other words, employing digital mechanisms in management processes enhances the capacity for innovation. Furthermore, Kaban and Tukiran (2023) identify dynamic capabilities as the foundation upon which companies can build digital transformation and remain competitive in the market.

Also related to digital transformation and innovation, Ciasullo and Lim (2022) highlight several important open questions in the literature, which this article aims to address and discuss. The open questions identified by the authors include: Which elements act as motivators or barriers to an innovation model through digital transformation? How and to what extent does digital transformation create value? What capabilities are necessary for digitalization and innovation? To what extent does digitalization drive innovation according to company size and/or sector?

The BRICS countries (Brazil, Russia, India, China, and South Africa) require improvements in innovation, as it presents both significant opportunities and complex challenges (Andrade & Gonçalo, 2021; Castellar et al., 2021). In the Brazilian context, particularly among small and medium-sized enterprises, digital transformation is a widely discussed topic but lacks conceptual clarity in the literature (Vasconcellos, 2020). New studies are

crucial to expanding knowledge and understanding of this topic. This study aims to contribute to addressing these gaps, particularly in the context of emerging countries and among types of companies that are under-researched.

Considering the benefits and challenges of digital transformation in MSMEs, as well as the focus on innovation and its potential for improvement, this article aims to address the following questions: *What is the influence of digital transformation on innovation? What is the moderating role of barriers to digitalization in this relationship?*

Thus, a study was conducted using data from a sample of 731 companies, collected by FAEDPYME researchers. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed for data analysis.

As a practical contribution, this study provides managers with valuable information to identify digitalization strategies and relevant technology usage that can drive innovation and competitiveness in small and medium-sized enterprises. The study also expands the discussion to include the difficulties encountered by MSMEs, which act as barriers to digitalization in the context of digital transformation. In Brazil, particularly in medium-sized enterprises, organizational culture emerges as a limiting and decelerating factor in the digital transformation process for innovation. Another finding of the research highlights the need for expansion and emphasizes the importance of technology usage in the business sphere, including areas such as e-commerce, data analysis software, cybersecurity, and process automation.

The research also contributes to academic advancement in the fields of digital transformation and innovation. The findings will be shared with the scientific community and the broader public, thereby enriching the academic debate and fostering further research in this area. This study addresses the existing gap in the literature regarding digitalization strategies and their application in innovative environments.

2. Literature review and research hypotheses

The ability to innovate is closely linked to the use of advanced technologies and market strategies. Big data tools have a notable positive influence on innovation processes in product development, highlighting the beneficial impact of technology and market strategies on innovation (Pinochet et al., 2021). The rapid evolution of digital technologies and their disruptive effects on stable economies underscore the parallels between digital transformation and reverse engineering, where product creation and analysis precede their recreation, fostering continuous cycles of innovation (McGrath & McManus, 2020). The COVID-19 pandemic accelerated digital transformation, with managers increasingly recognizing its necessity for crisis management. This shift is evident in the significant increase in the prioritization of digital transformation among managers, from 68% to 90% (Wade, 2021). The pandemic acted as an external catalyst for technology adoption in businesses, highlighting to owners the need to adapt to a new business framework (Costa et al., 2021).

While traditional companies collect data occasionally, companies like Google and Amazon capture a continuous stream of data on their platforms, thereby expanding business opportunities (Subramaniam, 2022a). Through digital platforms, companies such as Alibaba and Tencent provide various functionalities to SMEs, including digital payment services, e-commerce (digital stores), digital marketing, and logistics services (Subramaniam, 2022b). As a new business model, digital platforms leverage technology to connect resources, such as organizations and people (Parker et al., 2016).

Agile organizations rely on digital technology development metrics, market structuring, customer co-creation, and digital platform diversification (Verhoef et al., 2021). An example of this is the use of smart asthma inhalers, which not only provide medical benefits but also enable consumers to collect data that feeds predictive algorithms, showcasing a consumer achievement in leveraging technology (Mohammadi, 2017).

Furthermore, each business segment adapts to its digital needs without the risk of disruption (Furr & Shipilov, 2019). Addressing the digital challenge requires creating new business models to redefine relationships between companies, discovering innovative approaches, and leveraging social tools that engage customers and visionary leaders (Sanchez & Zuntini, 2018). In this context, dynamic capabilities enable companies to become more agile and achieve superior performance compared to their competitors (Mele et al., 2024).

However, the path to value creation for SMEs is unique, and expanding new digital businesses requires focus and adherence to the fundamental principles of the digital channel (Mandviwalla & Flanagan, 2021). Notably, the post-COVID-19 digital transformation has compelled small businesses in the food industry to remodel their operations to stay competitive, sometimes even without the owners' initial approval (Costa et al., 2021). It is therefore crucial to invest time and resources in training people to achieve a successful digital transformation (Cichosz et al., 2020).

Furthermore, consumer-oriented companies are adopting hybrid models that integrate both physical and digital elements, ensuring that while digital usage increases, physical assets such as documents and infrastructure do not entirely disappear (Furr & Shipilov, 2019). Even though conservative customers may prefer personal interaction, companies find it easier to transition functionalities to the digital medium through information-intensive services (Sanchez & Zuntini, 2018).

This trend is leading to a rise in Brazilian SMEs, driven by the adoption of innovation, technological capabilities, and management technologies, which contribute to regional and national development and enhance global competitiveness, similar to that of developed countries (I. P. Pereira, 2021). Digital maturity positively influences the development of Brazilian retail businesses (Salume et al., 2021). The positive impact of ICT usage by small businesses is also recognized as a significant innovation strategy (Alves & Silva, 2022).

Information technology faces various challenges, yet digital technologies provide a range of mechanisms that enhance the flexibility of products offered (von Briel et al., 2018). However, the vast majority of SMEs do not utilize technological tools to optimize business management(J. A. Pereira & Bernardo, 2016). One way that SMEs gain visibility is through the digital environment, particularly by leveraging the effects of social networks, such as Instagram (Vale & Santos, 2022). For traditional companies to remain competitive in the market, it is essential to adopt digital systems and capitalize on network effects, prompting a rethinking of their strategies (Bem et al., 2022).

Digital transformation, through digitalization strategies and technology usage, offers opportunities in the digital world, such as enhanced flexibility, customer-centric orientation, the development of new skills, and the adoption of emerging technologies, enabling companies to innovate (Furr & Shipilov, 2019). Although digital transformation only reaches its full potential when the environment is adequately prepared, the widespread adoption of technologies provides significant benefits to both society and the economy (Aleksandrova et al., 2022).

Innovating in business models is essential for adding value and achieving desired outcomes, particularly in a capabilities-based environment (Girardi, 2023). SMEs must not overlook the opportunities presented by digitalization and should embrace digital transformation as a driving force that is both ongoing and inevitable (Peillon & Dubruc, 2019).

Innovation through the use of big data plays a crucial role in enhancing the understanding of information generated by advanced technologies (Subramaniam, 2022a). The use of innovative technology forms the foundation for digital transformation (Gonçalves et al., 2023). To achieve this, having trained personnel is essential for managing digital resources and adapting internal processes (Subramaniam, 2022a).

This approach, combined with market-centric external analysis and value generation, allows organizations to gain control over various aspects of digital transformation and, consequently, increase their innovation capacity (Peter et al., 2020). Digital transformation also serves as a facilitator for enhancing the sustainability, efficiency, and effectiveness of products and services. It provides a range of benefits, from offering new types of services to optimizing customer experience and integrating value chains (Castellar et al., 2021).

A lack of clear understanding of digital transformation may hinder companies from learning how to compete effectively, potentially rendering their business models economically unviable (Sanchez & Zuntini, 2018). However, the use of digital tools allows companies to communicate more easily with customers and compete even with minimal resources (Pratama et al., 2021). Therefore, the impact of digital transformation can only be realized if the environment is prepared to embrace it (Aleksandrova et al., 2022).

Thus, digital transformation requires the involvement of the entire business, as it has a significant and positive impact on innovation. By empowering companies to adapt, innovate, and thrive in an increasingly digitalized business environment, digital transformation promotes continuous improvement and competitiveness.

  H1: *Digital transformation exerts a positive influence on innovation.*

Digital transformation is recognized as a complex and variable challenge for companies (Peillon & Dubruc, 2019). Several barriers can slow down or even halt the digital transformation process within companies (Vogelsang et al., 2019). Challenges such as a lack of resources, including time and technological infrastructure, can discourage companies from seeking external knowledge that could enhance their transformation efforts, ultimately limiting their entrepreneurial initiatives (J. A. Pereira & Bernardo, 2016).

Furthermore, the lack of security (Mohammadi, 2016; Papadopoulos et al., 2020) and financial resources (Austin et al., 2021; Cichosz et al., 2020; OECD, 2020; Peillon & Dubruc, 2019; J. A. Pereira & Bernardo, 2016) are significant barriers to digital transformation. Additionally, resistance to change is one of the major obstacles in the digital transformation journey. This resistance can stem from employees fearing job displacement due to technology and from managers who lack the technical knowledge necessary to effectively

implement digital transformation (Cichosz et al., 2020; Fountaine et al., 2019; Horváth & Szabó, 2019; Töytäry et al., 2017).

The digitalization process in logistics service companies is often challenging and time-consuming (Cichosz et al., 2020). SMEs, especially those in the early stages of digitalization, may encounter organizational or cultural barriers that hinder their development; however, digital transformation remains unavoidable (Peillon & Dubruc, 2019). A lack of skills is identified as a central barrier to digital transformation (Vogelsang et al., 2019).

Companies need to focus on internal efficiency to achieve a lasting impact, while also developing new capabilities and resources (Töytäry et al., 2017). To overcome these challenges, companies, particularly smaller ones facing more constraints than their larger counterparts, require creative solutions tailored to their specific circumstances (Mandviwalla & Flanagan, 2021). Additionally, appropriate systems should provide a secure infrastructure and ensure full-time availability (Papadopoulos et al., 2020).

Therefore, given the challenges companies face in digital transformation, it is hypothesized that these digitalization development barriers have a negative and significant influence on the relationship between digital transformation and innovation.

H2: *Digitalization development barriers negatively moderate the relationship between digital transformation and innovation.*

Figure 1. Theoretical model of the research
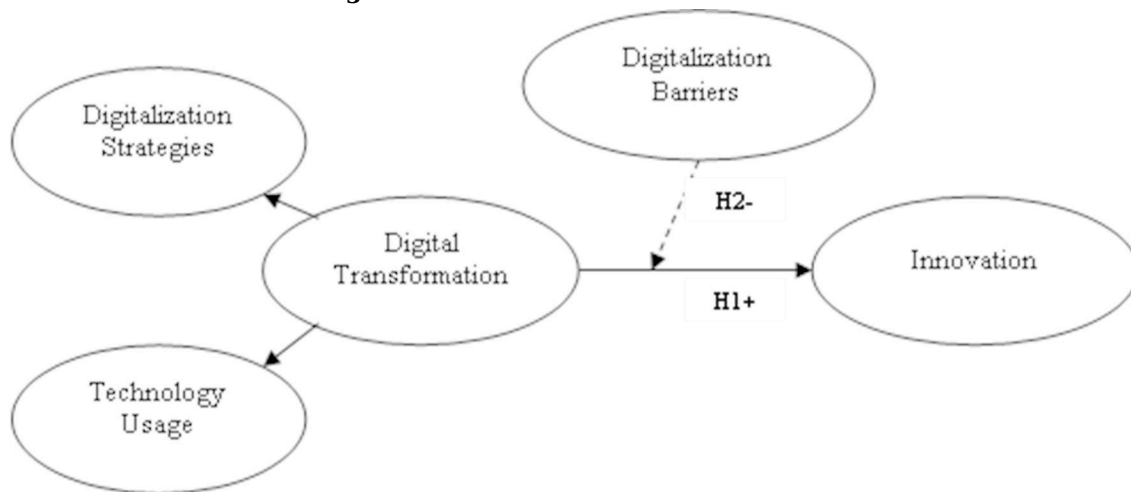
Source: Authors

Figure 1 illustrates the theoretical research model, incorporating the two hypotheses proposed in the study. Digital transformation is conceptualized as a second-order construct, comprised of digitalization strategies and technology use. The influence of this digital transformation construct on the innovation construct is examined. The construct of digitalization development barriers is introduced as a moderator in this relationship. Additionally, during the data analysis stage, the control variables "years of operation" and "size" were included.

3. Method

This research is the result of the work of the Ibero-American Observatory of Micro, Small, and Medium-sized Enterprises, which focuses on business development and entrepreneurship in Spain and Latin American countries. The study was conducted from February to May 2022. This initiative represents a strategic effort to enhance collaboration between university networks through the Foundation for Strategic Analysis and Development of Small and Medium-sized Enterprises (FAEDPYME). Additionally, it aims to improve segmentation by business sectors (FAEDPYME, 2022b).

This study is quantitative and exploratory in nature and is characterized as cross-sectional, capturing data on digital transformation, which can change rapidly. Cross-sectional studies involve samples of various units, such as individuals, families, and businesses, at a specific point in time. This approach is crucial for testing microeconomic hypotheses and evaluating economic policies (Wooldridge, 2016).

3.1 Sample and data collection

The population of this study consists of Brazilian micro, small, and medium-sized enterprises (MSMEs). It is important to note that terms related to microenterprises were identified specifically in studies conducted in Brazil, whereas in international studies, these are generally categorized as small businesses. The sample comprised 980 Brazilian companies, with "58.57% being microenterprises, 29.59% small, and 11.84% medium-sized enterprises" (FAEDPYME, 2022a).

Data collection was conducted by researchers from Brazilian universities affiliated with the Ibero-American Observatory of Micro, Small, and Medium Enterprises. The researchers distributed a link directing respondents to the platform where the survey instrument was hosted. The link was shared through various social networks, including WhatsApp, email, and LinkedIn.

One of the initial steps was to analyze the collected data. It was found that 249 responses were incomplete. Following the guidelines of Hair. et al. (2017), any cases with more than 10% missing data were excluded from the analysis. Consequently, a valid sample of 731 MSMEs remained.

To validate the sample, the G*Power 3.1.9.7 software was used to perform a post hoc test ("Compute achieved power"). Based on the effect size observed in the study (0.152), a significance level of 0.05, a sample size of 731, and two predictors, the power $(1-\beta$ err prob) was calculated to be greater than 0.99. This confirms that the sample is validated, as a power level greater than 0.80 is typically required (Cohen, 1992; Faul et al., 2009).

The data collection procedure was conducted using a survey. Questionnaires can range from fundamentally unstructured formats to highly structured formats, such as those using objective questions (Cooper & Schindler, 2016). The questionnaire in this study was designed to facilitate comprehensive data collection, focusing on innovation, digitalization strategies, technology use, and digitalization development barriers.

3.2 Measures and variables

Table 1 presents the latent and observed variables used to form the analytical structure of the hypothesis model proposed in this research. The latent dependent variable, innovation, was measured using seven observed variables (IN1 to IN7) on a five-point Likert scale (1 = not important; 5 = very important). Respondents were also given the option to select zero, indicating that no innovations had been made in the last two years. This measure of innovation has been employed in several empirical studies (Oro et al., 2024; Restrepo-Morales et al., 2024; Rubio-Andrés et al., 2023).

The latent independent variable, digital transformation, was conceptualized as a second-order construct, measured by two first-order latent variables: digital strategy and technology use. To estimate the latent variable digital strategy, eight observed variables (DTS1 to DTS8) were used, each measured on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). This measure of digital strategy has been applied in several studies (Oro et al., 2024; Santos-Jaén et al., 2023). To measure the latent variable technology usage, twelve observed variables (DTU1 to DTU12) were employed, also using a five-point Likert scale (1 = not important; 5 = very important), with an additional option of zero to indicate no use. This measure of technology use has been utilized in various studies (Almendros et al., 2022; Begnini et al., 2024; Carrascal & Perez, 2023).

Table 1. Latent and observed variables

Latent Variables	Observed Variables
Innovation (IN)	IN1. Changes or improvements in existing products/services
	IN2. Launching new products/services in the market
	IN3. Changes or improvements in production processes
	IN4. Acquisition of new capital goods
	IN5. Changes or improvements in organization and/or management
	IN6. Changes or improvements in purchasing and/or acquisition of inputs
	IN7. Changes or improvements in company sales and/or marketing
Digital Strategies (DTS)	DTS1. We are familiar with the possibilities and advantages of digitalization
	DTS2. We allocate significant resources to digitalize the business
	DTS3. The business model is evaluated and updated in terms of digitalization
	DTS4. Our employees are prepared for the digital development of the company
	DTS5. Our managers have good training in digitalization
	DTS6. The degree of process automation is high in my company
	DTS7. We use digitalization in the organizational management of the company

Table 1. Latent and observed variables

Latent Variables	Observed Variables
	DTS8. In our company, training for digital transformation is regularly conducted
Technology Usage (DTU)	DTU1. Having a website
	DTU2. We conduct sales on our own e-commerce portal (via the Internet)
	DTU3. We engage in e-commerce on the Marketplace (Amazon or equivalent)
	DTU4. Use of social media for commercial purposes
	DTU5. Use of digital banking
	DTU6. Telecommuting (home office)
	DTU7. Use of ERP (Enterprise Resource Planning) systems
	DTU8. Corporate intranet
	DTU9. Use of services for cybersecurity
	DTU10. Use of data analysis software and big data
	DTU11. Use of robotics, sensor technology
	DTU12. Use of location-based services, Internet of Things
Digitalization Barriers (DB)	DB1. Insufficient broadband connectivity
	DB2. Lack of financial resources in the company
	DB3. High investment costs
	DB4. Digitalization may be poorly received by workers
	DB5. Lack of well-qualified personnel that are difficult to find and retain
	DB6. Lack of awareness about technology providers
	DB7. Necessary information technology security requirements (cybersecurity)
	DB8. Lack of corporate culture to drive (stimulate) digital transformation

Source: Authors

The first-order latent mediating variable, barriers to digitalization, was measured using eight observed variables (DB1 to DB8) on a five-point Likert scale (1 = not important; 5 = very important). The construct "barriers to digitalization" has been utilized in previous studies (Begnini et al., 2024; Chen et al., 2021).

3.3 Data analysis

Structural Equation Modeling (SEM) was employed for hypothesis testing and analyzing the results. Specifically, the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique was utilized, which has become a highly advantageous approach for analyzing interactions between constructs estimated by complex models (Bido & Da Silva, 2019). PLS-SEM is particularly suitable for research in exploratory fields and those investigating relatively new relationships (García-Machado et al., 2023). This approach is appropriate for the present study, which seeks to understand the relationship between digital transformation, barriers to digitalization, and innovation in Brazilian SMEs—an area still developing theoretically. PLS-SEM is preferred in such contexts because it is less stringent in terms of pre-existing theoretical requirements compared to Covariance-Based SEM (CB-SEM) (Hair. et al., 2017). Additionally, PLS-SEM can be applied to both formative and reflective models (Dash & Paul, 2021) and has strong support from numerous researchers (Astrachan et al., 2014; Rigdon, 2016; Sarstedt et al., 2016).

Given that this study utilized only reflective constructs, consistent PLS-SEM (PLSc-SEM) was employed to provide consistent estimates for reflective models. PLSc-SEM allows for the calculation of consistent estimates for path coefficients, equation parameters, construct correlations, and indicator loadings (Dijkstra & Henseler, 2015). Following the guidelines provided by Hair. et al. (2017), we assessed the measurement model by calculating the Average Variance Extracted (AVE), Cronbach's Alpha (CA), and Composite Reliability (CR). Additionally, we applied the Fornell-Larcker Criterion and examined cross-loadings of the observed variables. For the structural model, we analyzed t-test values, p-values, R^2, and effect sizes (f^2).

The application of validation tests ensured the reliability of the models, confirming that the constructs and variables were assessed accurately. Adhering to these criteria strengthens the credibility of the conclusions drawn from this research.

4. Results

The results are based on a representative sample of 731 Brazilian micro, small, and medium-sized enterprises. The characterization of the sample companies is provided, followed by the statistical results of the constructs. Hypothesis testing was subsequently performed using SmartPLS 4.0 software, applying structural equation modeling (Ringle et al., 2014). The section concludes with a discussion of the findings.

4.1 Firm characteristics and descriptive statistics

Table 2 presents the characteristics of the sample companies in this study, providing a comparison based on years of operation and firm size.

Table 2. Years of operation and firm size

Time	Micro Frequency	%	Small Frequency	%	Medium Frequency	%	Total Frequency	%
Less than 10 yrs	232	54.33	80	37.21	23	25.84	335	45.83
11 to 30 yrs	157	36.77	96	44.65	37	41.57	290	39.67
31 to 50 yrs	34	7.96	31	14.42	18	20.22	83	11.35
More than 51 yrs	4	0.94	8	3.72	11	12.36	23	3.15
Total	427	58.41	215	29.41	89	12.18	731	100.00

The research sample consists of 427 microenterprises, 215 small businesses, and 89 medium-sized companies. The majority of the sample are microenterprises, comprising 58.41% of the total. An important aspect of the study is the distribution of company longevity. It is noted that 45.83% of the companies have been operating for less than 10 years, indicating that early-stage businesses make up a significant portion of the business landscape. In contrast, only a small fraction, 3.15%, have been in operation for over 51 years, underscoring the relatively young nature of most companies in the sample.

The descriptive statistics of the 731 companies under study are presented in Table 3. These data provide a foundation for understanding the distribution and variation among the variables.

Table 3. Descriptive statistics

Latent Variable	N	Mean	St. Deviation	Minimum	Maximum
Technology Usage (DTU)	731	1.94	1.98	0	5
Digitalization Strategies (DTS)	731	3.08	1.38	1	5
Digitalization Barriers (DB)	731	3.28	1.41	1	5
Innovation (IN)	731	3.39	1.75	0	5

It is observed that all variables— Technology Usage (DTU), Digitalization Strategies (DTS), Digitalization Barriers (DB), and Innovation (IN)—have a total of 731 respondents, with most variables showing an average score of 3. However, the DTU variable has a mean score of 1.94, suggesting that the companies in the study have a low level of technology usage in their processes.

The minimum response value for the DTU and IN variables was 0, and the maximum was 5, while for the DTS and DB variables, the minimum value was 1 and the maximum was 5. The standard deviation values are within the expected range, indicating little dispersion of data around the mean.

4.2 Investigation of the measurement model

Table 4. Validity and reliability of the measurement model

Research Model	Constructors						
First-order Model							
Variable	Barriers	Innovation	Strategies	Usage	AC	CC	AVE
Barriers	**0.730**				0.822	0.871	0.533
Innovation	0.226	**0.780**			0.892	0.916	0.609
Strategies	0.269	0.372	**0.797**		0.917	0.933	0.635
Usage	0.278	0.337	0.575	**0.723**	0.846	0.884	0.523
Structural Model							
Variable	Barriers	Digital Transformation		Innovation	AC	CC	AVE
Barriers	**0.730**				0.822	0.871	0.533
Digital Transformation	0.306	**0.884**			0.892	0.916	0.609
Innovation	0.226	0.402		**0.780**	0.915	0.877	0.782

Table 4 presents the validity and reliability of the measurement model, which comprises reflective constructs. The digital transformation construct, considered a second-order construct, is composed of the digitalization strategies and technology usage constructs.

The validity and reliability of the constructs are detailed in Table 4, which is divided into two sections corresponding to the stages of the research model. The first section highlights the results for the first-order model, while the second section presents data for the structural model, including the second-order construct. To ensure convergent validity, as indicated by an Average Variance Extracted (AVE) of at least 0.5 (Fornell & Larcker, 1981), it was necessary to exclude the observed variables DB2, DB3, DTU2, DTU3, DTU4, DTU5, and DTU6, as shown in Table 5.

Table 5. Initial and final loads with reason for exclusion

Variable	Initial Load	Final Load	Variable	Initial Load	Final Load
DB1	0.574	0.565	DTS4	0.804	0.803
DB2	0.495	Excluded*	DTS5	0.821	0.821
DB3	0.533	Excluded*	DTS6	0.816	0.817
DB4	0.682	0.694	DTS7	0.822	0.822
DB5	0.784	0.794	DTS8	0.788	0.788
DB6	0.807	0.818	DTU1	0.600	0.580
DB7	0.771	0.780	DTU10	0.753	0.807
DB8	0.693	0.700	DTU11	0.705	0.744
OI1	0.750	0.750	DTU12	0.690	0.702
OI2	0.736	0.732	DTU2	0.520	Excluded*
OI3	0.833	0.835	DTU3	0.523	Excluded*
OI4	0.733	0.736	DTU4	0.367	Excluded*
OI5	0.820	0.822	DTU5	0.421	Excluded*
OI6	0.776	0.774	DTU6	0.388	Excluded*
OI7	0.806	0.805	DTU7	0.689	0.705
DTS1	0.689	0.689	DTU8	0.686	0.721
DTS2	0.804	0.803	DTU9	0.724	0.784
DTS3	0.823	0.823			

(*) Excluded to improve AVE

Thus, the constructs also achieved the necessary reliability, as measured by internal consistency using Cronbach's Alpha (CA) and Composite Reliability (CR) (Hair. et al., 2017). Additionally, discriminant validity at the construct level, assessed using the Fornell-Larcker criterion (1981), was confirmed, with the square roots of the AVEs exceeding the correlations between constructs, as shown in the first columns of Table 4.

4.3 Hypothesis testing

Figure 2 presents the results of the hypothesis testing conducted to validate the research model.

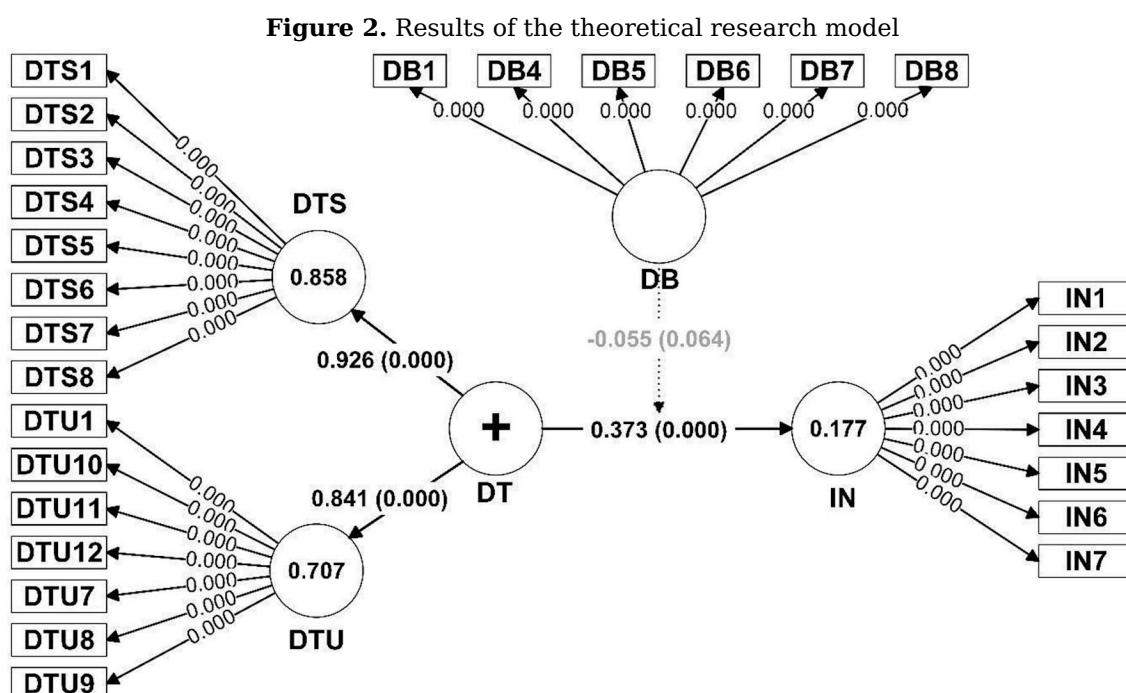**Figure 2.** Results of the theoretical research model

Figure 2 illustrates the theoretical research model, as previously identified in Figure 1. The results confirm the first research hypothesis (H1), demonstrating that digital transformation has a positive and significant influence on promoting innovation. However, the second research hypothesis (H2) was rejected, indicating that barriers to digitalization development do not significantly hinder the relationship between digital transformation and innovation. This finding offers a deeper understanding of the interaction between digital transformation and the factors that may constrain innovation.

Table 6. Hypothesis testing

Hyp	Relation	Struct. Coef.	St. Deviation	T Test	P Value	r^2	f^2	Result
H1	Digital Transf. -> Innovation	0.373	0.033	11.325	0.000	0.177	0.152	Supported
H2	Barriers x Digital T. -> Innovation	-0.055	0.030	1.854	0.064			Rejected

Table 6 presents the results obtained from the hypothesis testing. As previously mentioned, hypothesis H1 was confirmed, while hypothesis H2 was rejected. The confirmation of H1 is supported by a p-value of 0.000, fully endorsing the hypothesis. The structural coefficient, or the strength of the explanation, is 0.373, contributing to a variance in the data of 17.70%. According to the classification by Hair. et al. (2017), this hypothesis exhibits a medium effect size, with an index of 0.152. These results highlight the relevance and significant influence of H1, underscoring its contribution to a deeper understanding of the effects of digital transformation on innovation.

In contrast, the second research hypothesis, H2, was refuted. While the structural coefficient shows a negative value of -0.055, suggesting that barriers to digitalization may negatively influence the relationship between digital transformation and innovation, the p-value of 0.064 led to the rejection of H2. This finding indicates insufficient statistical significance to support the moderation effect proposed by the hypothesis, highlighting the complexity of the relationship and the need for further analysis to fully understand the factors influencing this specific dynamic.

Given the rejection of hypothesis H2, further efforts were made to explore explanations for the observed negative structural coefficient, as initially proposed. Table 7 presents additional analyses to contextualize this result, including the control variables "years of operation" and "firm size".

Table 7. Control variables

Relation	Struct. Coef.	St. Deviation	T Test	P Value
Control: PORTE -> Innovation	0.064	0.033	1.979	0.048
Control: TO -> Innovation	-0.101	0.030	3.372	0.001

During the testing process, we included the control variables "years of operation" (TO) and "firm size" (PORTE), as shown in Table 6. Both variables demonstrated statistical significance, with p-values of 0.001 and 0.048, respectively. In this research context, we chose to focus the analysis on "firm size," given the study's objective to deepen the understanding of Brazilian SMEs. This strategic focus allows for a more specific examination of the effects of barriers related to firm size and scale, thereby enriching the research. Consequently, Figures 3, 4, and 5 provide analyses subdivided into Micro, Small, and Medium-sized companies, respectively.

Figure 3 presents the structural model analysis conducted exclusively with microenterprises, offering a detailed perspective on the dynamics within this business segment.

Figure 3. Results of the theoretical model of the research – microenterprises
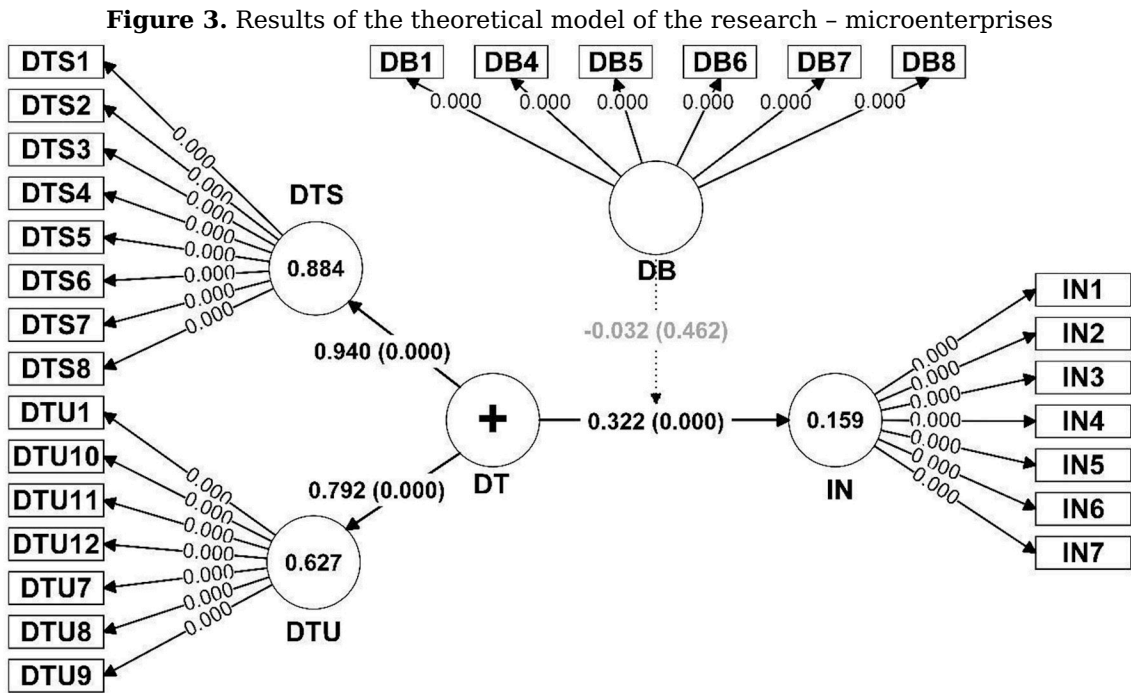

Figure 3 details the analysis of the 427 microenterprises included in the study. With a p-value of 0.462, the results do not demonstrate statistical significance to support the proposed explanation. However, the negative structural coefficient of -0.032 introduces additional complexity to the interpretation of the results.

Figure 4 presents the structural model analysis conducted exclusively with small enterprises, providing a detailed view of the dynamics within this business segment.

Figure 4. Results of the theoretical model of the research – small enterprises
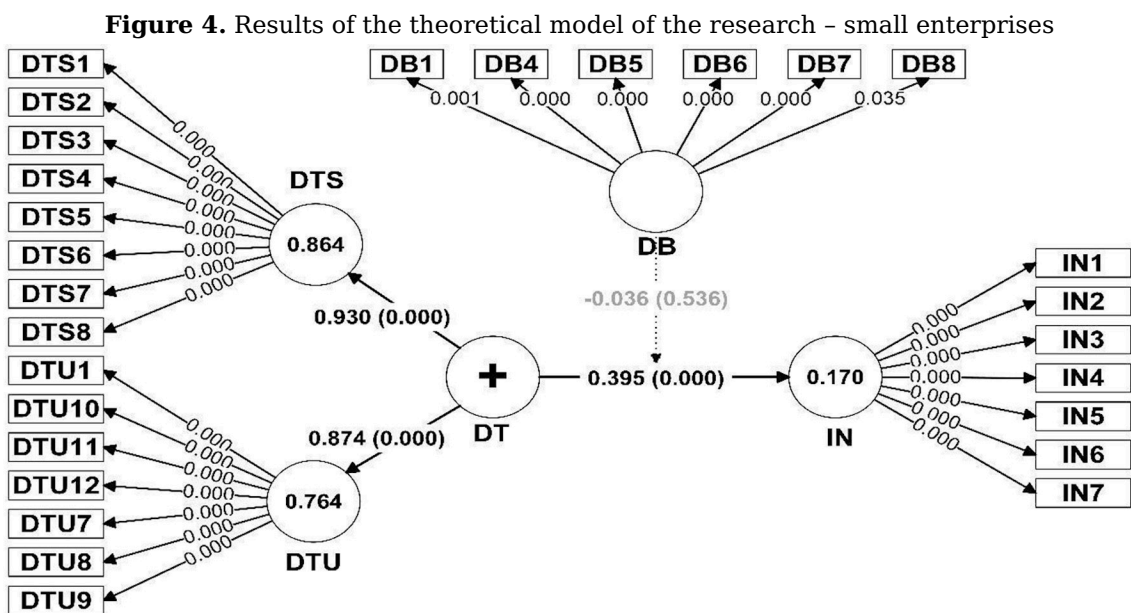

Figure 4 illustrates the analysis of the 215 small enterprises included in the sample. With a p-value of 0.536, the results do not provide sufficient statistical significance to support the proposed explanation. Similar to the findings for microenterprises, the small enterprises also display a negative structural coefficient of -0.036, complicating the interpretation of the results.

Figure 5, in contrast, presents the structural model analysis conducted exclusively with medium-sized enterprises, providing a detailed perspective on the dynamics within this business segment.
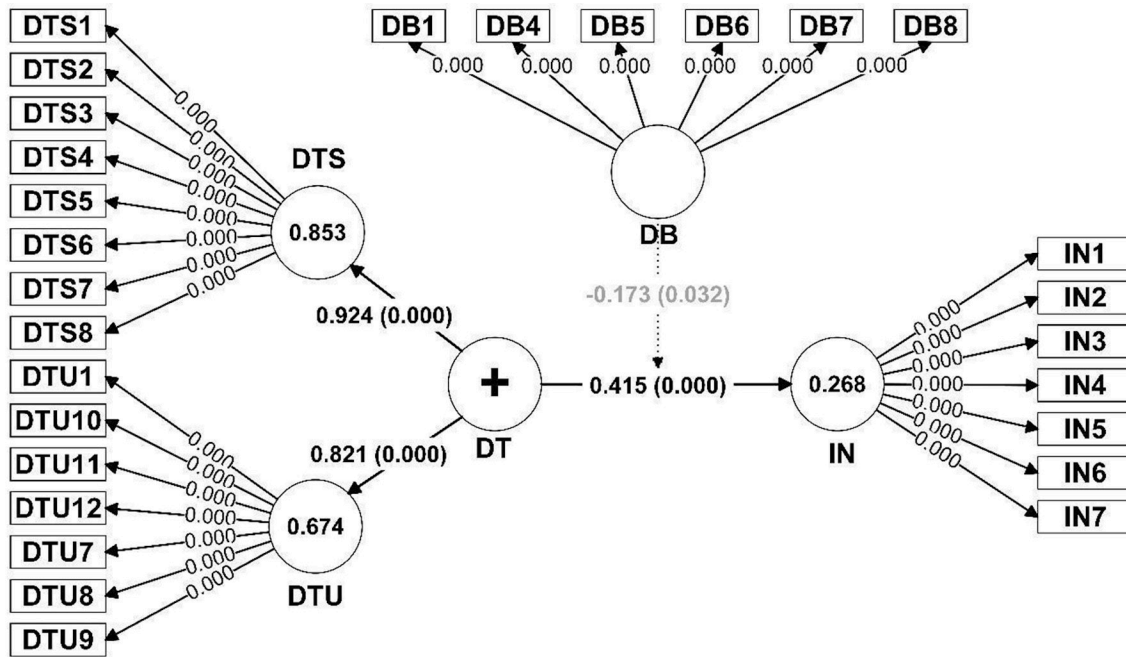
Figure 5. Results of the theoretical model of the research – medium-sized enterprises

Figure 5 presents the results from the analysis of medium-sized enterprises in the sample. For this group, a p-value of 0.032 and a structural coefficient of -0.173 validate the proposed explanation for hypothesis H2. The results indicate statistical significance, supporting the hypothesis that barriers to digitalization negatively influence the relationship between digital transformation and innovation. This finding suggests that, within the context of this study, the larger the business size, the more significant the barriers to digitalization become as obstacles in the process of digital transformation toward innovation.

5. Discussion

The research findings indicate that digital transformation, facilitated by digitalization strategies and the use of technologies, positively impacts innovation. While there are barriers in this process, they do not have sufficient strength to significantly impede it. This suggests that micro, small, and medium-sized enterprises (MSMEs) that invest in technology use and digitalization strategies are likely to enhance their levels of innovation.

The results validate the first hypothesis (H1), supporting the assertion that business models which are continually assessed and updated for digitalization, and those incorporating technologies in the corporate environment, facilitate improvements and innovations in products introduced to the market. This finding aligns with the study by Pinochet et al. (2021), which emphasizes the positive influence of technology and market strategies on the product innovation process.

With the validation of hypothesis H1, it is evident that digital transformation positively impacts innovation in Brazilian MSMEs. As noted by Furr and Shipilov (2019), digital transformation provides opportunities in the digital realm, such as developing new skills and adopting emerging technologies, enabling companies to innovate.

Previous studies, such as those by Vale and Santos (2022), have indicated that SMEs gain visibility through the digital environment and benefit from network effects, such as those seen on platforms like Instagram. These findings reinforce the idea that leveraging digital tools, including e-commerce and social networks, can facilitate organizational innovations.

However, this positive impact is not yet fully realized among SMEs, as the majority still do not utilize technological tools to enhance business management (J. A. Pereira & Bernardo, 2016). Our findings support this assertion, showing that 48.52% of MSMEs do not incorporate technologies in their operations. This represents a significant challenge, as many small businesses are not taking advantage of the potential benefits that technology can offer. The failure to leverage these tools creates a gap that may affect the adaptability of these companies in the contemporary market, where the use of technology is fundamental.

Adapting to digital transformation enables organizations to enhance their innovation capabilities. As noted by Peter et al. (2020), an external analysis focused on value generation allows organizations to manage various dimensions of digital transformation and, consequently, increase their capacity for innovation. With the

substantial increase in digital users, adapting to digital transformation has become essential for businesses. The annual growth in internet users has led to a significant expansion, rising from 2.2 billion in 2012 to 4.4 billion in 2019, resulting in increased data interaction (Subramaniam, 2022a). The findings of this study suggest that by embracing digital transformation, MSMEs are on a promising path toward continuous innovation and aligning with the expectations of the digital landscape.

Contrary to expectations, the second research hypothesis (H2) was rejected, as the results did not provide sufficient evidence to suggest that barriers to digitalization development negatively influence the relationship between digital transformation and innovation in Brazilian MSMEs. It was anticipated that these barriers would impede the innovation process. However, Wade (2021) notes that the COVID-19 pandemic actually accelerated digital transformation, with the percentage of managers prioritizing digital transformation increasing from 68% to 90% in the post-pandemic period.

However, when hypothesis H2 is analyzed by firm size, it becomes evident that barriers to digitalization development negatively influence the relationship between digital transformation and innovation in medium-sized enterprises. Our findings indicate that these barriers particularly hinder innovation in larger companies. Experienced companies in digitalization have noted that attempts to replace multiple, carefully designed complex systems all at once often lead to failure (Furr & Shipilov, 2019).

Furthermore, a lack of financial resources (OECD, 2020) may be a significant challenge for medium-sized companies. While micro and small businesses often operate with leaner structures and may be more agile in adopting accessible technologies, medium-sized companies may face considerable difficulties in implementing innovative technologies. In this context, the lack of financial resources can become a substantial barrier to digitalization (Peillon & Dubruc, 2019).

In micro and small businesses, barriers may not significantly affect innovation due to the early stage of development of these companies, which provides more opportunities for digitalization and innovation. Their agility allows them to adapt more easily to changing environments, often without the bureaucratic processes that can hinder larger companies. According to J. A. Pereira and Bernardo (2016), 87% of Brazilian micro and small businesses did not use digital platforms for management. This suggests that these companies may be more adept at finding solutions when faced with difficulties.

Although micro and small businesses encounter their own set of challenges, their more agile structures and flexible cultures often enable them to overcome barriers and adopt digitalization for innovation more efficiently than medium-sized enterprises. However, it is important to note that digital transformation, in itself, is not a familiar environment for most companies, which frequently struggle to navigate the challenges it presents (Peillon & Dubruc, 2019).

6. Conclusions and recommendations

This study aimed to analyze the influence of digital transformation on innovation, with a focus on the moderating role of barriers to digitalization development in micro, small, and medium enterprises (MSMEs) in Brazil. The research was conducted using data from a sample of 731 companies, collected by FAEDPYME researchers.

The results indicate that digital transformation, through the use of technologies and digitalization strategies, has a positive and significant impact on innovation (hypothesis H1) in Brazilian micro, small, and medium-sized enterprises. The findings also suggest that, despite the presence of barriers to digitalization development, these barriers do not directly affect this relationship (hypothesis H2), except in the case of medium-sized companies. Additionally, the theory of Dynamic Capabilities (DCs) emerges as a compelling framework for understanding digital transformation, as it highlights the importance of creating value to maintain competitiveness.

In innovation-driven environments, MSMEs prioritize the use of technologies and strategies to enhance digitalization and facilitate digital transformation. Similarly, acknowledging that companies are composed of teams of individuals, the study highlighted the importance of preparing both managers and employees for digital transformation, which is crucial for fostering successful innovation. Leaders must clearly communicate a vision centered around a common objective to the entire organization (Fountaine et al., 2019). Additionally, the availability of appropriate software and technological solutions is essential for supporting this process.

This study has several practical implications. It provides evidence to MSME managers that developing customized digitalization strategies can enhance the positive impact on innovation. Additionally, the adoption of specific technologies—such as e-commerce, social media, big data, cybersecurity, and process automation—should be considered to foster innovation and improve operational efficiency. The use of digital platforms can broaden a company's reach and interaction with customers, while marketplaces, social networks, and other platforms enhance visibility and competitiveness.

Furthermore, our study reveals that many micro and small enterprises (MSMEs) in Brazil do not adopt technologies in their operations. This lack of adoption represents a significant barrier, as numerous small businesses are not leveraging the benefits that technology offers. The absence of these technological tools can create a gap that impedes these companies' ability to adapt in a modern market that places a high value on technology. This article addresses these gaps and contributes to advancing the understanding of digital transformation in MSMEs, which have unique structures and implications for calibrating performance and fostering innovation (Verhoef et al., 2021).

Considering the findings, several aspects warrant attention: (i) The use of e-commerce, either through a company's own portal or a marketplace, is advantageous, as many small companies utilize marketplaces to achieve broader market reach (OECD, 2020); (ii) Technologies such as social media, the Internet of Things, robotics, big data, and other software have a substantial impact on innovation. Competitive advantage can be driven by emerging technologies like sensors, the Internet of Things, and artificial intelligence (Subramaniam, 2022a); (iii) An updated business model and a team well-prepared for digitalization positively influence innovation practices. Each business segment can adapt to its specific digital needs (Furr & Shipilov, 2019); (iv) High levels of business process automation are beneficial for organizations. Digital transformation offers methods to enhance innovation, efficiency, and the effectiveness of products and services, including automated activities, as exemplified by Magazine Luiza (Castellar et al., 2021).

In conclusion, digital transformation, facilitated by the use of technologies and digitalization strategies, is crucial for Brazilian MSMEs. While medium-sized companies may encounter specific challenges that can slow down the process of digital transformation and innovation, the need for adaptive and flexible approaches to overcome these barriers is evident. To address these challenges, Töytäry et al. (2017) suggest that companies should focus on enhancing internal efficiency to achieve lasting impact, thereby acquiring new capabilities and resources.

As for the limitations of this research, one key issue is that it relies on a preformulated data collection. Consequently, the constructs for technology use and innovation, which included a "does not use" response option, may have yielded different results compared to using a more restricted response scale, such as a 1 to 5 Likert scale.

As suggestions for future studies, it is recommended to investigate the reasons why barriers to digitalization development do not significantly influence the relationship between digital transformation and innovation. Given that this study adopts a cross-sectional approach to digital transformation, a longitudinal study with the same constructs may yield different results. It is also suggested to incorporate temporal comparisons, focus on family businesses, conduct analyses in large companies, and pursue more comprehensive research.

Acknowlegements

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