

The digital transformation process in SMEs: the role of managerial and organizational characteristics

El proceso de transformación digital en las pymes: el papel de las características directivas y organizativas

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- Article received:

16 June, 2025

- Article accepted:

23 January, 2026

- Published online in articles in advance:

22 April, 2026

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DOI:

<https://doi.org/10.18845/te.v20i2.8630>

Abstract: This study, based on the Technology-Organization-Environment (TOE) framework and Upper Echelon Theory, aims to identify the managerial and organizational factors influencing the digital transformation (DT) of small and medium-sized enterprises (SMEs) in Bulgaria. Data for the study were collected via a questionnaire applied to a sample of 338 Bulgarian SMEs. The factor analysis yielded seven factors: performance, digital strategy, perceived barriers, state support, external factors, technology usage, and DT adoption. These factors were used as new composite variables for the cluster analysis, which produced a three-cluster solution featuring two highly distinct clusters and one intermediate cluster. The first cluster had the highest values for all factors except perceived barriers, whereas the third cluster had the lowest values for all factors. The results show that manager characteristics moderate the effects of TOE factors on SME DT, shaping how these factors are understood, utilized, and ultimately applied to DT. The factors of SMEs' DT are positively correlated with managers' work experience and education, top management support, employee skills, firm's size, and the manufacturing, high-technology, and knowledge-intensive sectors. No significant differences were found for firm or manager age or gender. These findings could inform government policies aimed at providing targeted DT support to specific groups of SMEs.

Keywords: SMEs, digital transformation, clusters, TOE model, managerial and firm characteristics.

Resumen: Este estudio, basado en el esquema Tecnología-Organización-Entorno (TOE) y la Teoría del Escalón Superior, tiene como objetivo identificar los factores gerenciales y organizacionales que influyen en la transformación digital (DT) de las pequeñas y medianas empresas (pymes) en Bulgaria. Los datos para el estudio se recopilaron mediante un cuestionario aplicado a una muestra de 338 pymes búlgaras. El análisis factorial arrojó siete factores: rendimiento, estrategia digital, barreras percibidas, apoyo estatal, factores externos, uso de tecnología y adopción de DT. Estos factores se utilizaron como nuevas variables compuestas para el análisis de conglomerados, que

produjo una solución de tres conglomerados que presenta dos conglomerados muy distintos y un conglomerado intermedio. El primer conglomerado tuvo los valores más altos para todos los factores excepto las barreras percibidas, mientras que el tercer conglomerado tuvo los valores más bajos para todos los factores. Los resultados muestran que las características del gerente moderan los efectos de los factores TOE en la DT de las pymes, lo que configura cómo estos factores se entienden, utilizan y, en última instancia, se aplican a la DT. Los factores de la transformación digital de las pymes se correlacionan positivamente con la experiencia laboral y la formación de los directivos, el apoyo de la alta dirección, las competencias de los empleados, el tamaño de la empresa y los sectores manufacturero, de alta tecnología e intensivo en conocimiento. No se encontraron diferencias significativas en cuanto a la edad o el género de la empresa o del directivo. Estos hallazgos podrían fundamentar las políticas gubernamentales destinadas a brindar apoyo específico a la transformación digital de grupos específicos de pymes.

Palabras clave: Pyme, transformación digital, clústeres, modelo TOE, características de la gestión y de la empresa.

1. Introduction

In the digital economy, most enterprises are undergoing digital transformation (DT) to gain a competitive advantage (Eller *et al.*, 2020; Jie *et al.*, 2025). For small and medium-sized enterprises (SMEs), DT can facilitate access to markets and improve collaboration, communication, customer satisfaction, and innovation opportunities (Barragan & Becker, 2025; Lafuente *et al.*, 2023). These benefits are recognised as key drivers of DT adoption and encourage SMEs to embrace it to achieve long-term success (Lafuente *et al.*, 2022).

However, despite these potential advantages, SMEs continue to lag behind larger firms (Faiz *et al.*, 2024; Escribá-Carda *et al.*, 2024). For instance, the adoption of digital technologies remains limited among SMEs in the European Union (EU) (Holl & Rama, 2024), particularly in Bulgaria. According to the 2022 Digital Economy and Society Index (DESI), Bulgaria ranks 26th out of the 27 EU member states (European Commission, 2024).

Studies show that SMEs face significant difficulties in the digitalization process. Their ability to adopt new technologies is constrained by their small size, limited financial and human resources, inadequate infrastructure, and a lack of long-term strategies for data management and cybersecurity (Escribá-Carda *et al.*, 2024). Therefore, a better understanding of the factors influencing DT adoption in SMEs is needed (Dörr *et al.*, 2023).

The Technology-Organization-Environment (TOE) model (Tornatzky & Fleischer, 1990) is one of the common frameworks for investigating DT. However, the TOE dimensions are rather broad and therefore difficult to apply in specific contexts. Awa *et al.* (2017) argue that to specify the factors influencing DT adoption in SMEs, the TOE framework must be integrated with other theories that account for individual contexts. Specifically, the Upper Echelon Theory (UET) emphasizes the importance of the individual characteristics of top managers. According to UET, top managers' personality traits shape their interpretation of situations, influencing strategic decisions regarding technology adoption (Hambrick & Mason, 1984; Lafuente *et al.*, 2021). Therefore, integrating the two theories can reveal the interaction between the TOE's macro-level factors and the UET's micro-level characteristics of managers with regard to DT in SMEs (Bekos & Chari, 2025). The individual characteristics of managers shape their perceptions of new technologies, thereby acting as filters that moderate the influence of TOE factors (Li *et al.*, 2024). Consequently, alongside TOE factors, researchers also consider the impact of managers' and firms' demographic characteristics, such as age, education, work experience, gender, firm size, and industry, on technology implementation (Centobelli *et al.*, 2022).

Although SMEs play an important role in the global and national economies, research on their DT remains fragmented (Dörr *et al.*, 2023; Jie *et al.*, 2025). In particular, there is a lack of empirical studies on DT factors, creating

a knowledge gap (Kallmuenzer et al., 2025). Previous research has yielded inconclusive results regarding differences based on the demographic characteristics of SME entrepreneurs. For example, Plečko et al. (2023) found no differences in the use of digital technologies based on age, gender, education, or work experience, which contradicts the findings of other studies (Eze et al., 2023; Quaye et al., 2024). These discrepancies highlight the need for further research to understand how different types of SMEs achieve DT.

The heterogeneity of SMEs in relation to DT enables them to be segmented into groups with shared characteristics (Lafuente et al., 2023). For instance, Centobelli et al. (2022) examined the adoption of intra- and inter-organizational digital infrastructures in 6,178 Italian start-ups and proposed a four-group taxonomy: digital follower, technical influencer, social influencer, and digital leader. The present study responds to the call to examine SME heterogeneity (Faiz et al., 2024) by categorizing firms based on DT factors, as well as on characteristics of managers and firms. The study uses the TOE framework to identify SME subgroups, and then combines it with the UET to reveal the moderating effects of demographics in cluster profiles. The research questions are the following:

1. What TOE factors are related to DT in SMEs?
2. What are the main clusters of SMEs according to these factors?
3. What demographic characteristics of managers (UET) and firms moderate the effects of TOE factors on SME cluster profiles related to DT?

The study used data collected via a standardized questionnaire from 338 SMEs in Bulgaria. This data was then processed using factor and cluster analyses. The factor analysis identified seven factors related to DT, while the cluster analysis resulted in a three-cluster solution. The first cluster exhibited the highest values on all factors except perceived barriers, while the third cluster was its complete opposite. The results show that firm size, manufacturing, high-technology and knowledge-intensive sectors, managers' work experience and education, top management support (TMS), and employee skills are all positively related to the DT factors. No significant differences were found according to the age or gender of the firm or the manager.

The study contributes to the existing literature by highlighting the improved interpretative power of synergistic use of TOE factors and UET characteristics to understand the heterogeneity of the SME clusters regarding DT. The important moderating role of managerial and firm characteristics shows how TOE factors influence DT adoption in SMEs differently. At a practical level, these findings call for more adapted policies to support DT adoption in different groups of SMEs.

The remainder of this paper is organized as follows. First, the literature review discusses the importance of identifying external and internal factors related to SME digital transformation. Next, the research methodology, main results, discussion, and conclusions are presented.

2. Literature Review

2.1. TOE Model and Upper Echelon Theory

The Technology-Organization-Environment (TOE) model is widely used by researchers to examine DT in SMEs. Within this framework, technological factors refer to a firm's internal digital equipment and externally available technologies, as well as the perceived benefits, barriers, compatibility and complexity of these technologies (Faiz et al., 2024). Organizational factors include TMS, digital strategy, and the human and other resources (Faiz et al., 2024). Environmental factors relate to pressures from competitors, suppliers, customers, and government regulations (Luo & Yu, 2022). Studies confirm that these factors significantly influence DT and innovative performance in SMEs (Hu et al., 2024).

Despite its critical role in DT adoption (Nambisan *et al.*, 2017), the TOE model does not focus on the individual characteristics of SME owners/managers (Awa *et al.*, 2017). Upper Echelon Theory (UET) addresses this gap by asserting that strategic decisions, including those relating to technology implementation, are influenced by the characteristics of senior managers (Hambrick & Mason, 1984; Lafuente *et al.*, 2021). While the TOE framework highlights the importance of technological, organizational, and environmental factors, UET positions managerial characteristics as an important moderator that shapes the perception of these factors and ultimately affects technology adoption decisions. For instance, Religia *et al.* (2025) found that digital leadership negatively moderated the effect of organizational context on CRM adoption among SMEs. Consequently, the combined influence of managerial characteristics and TOE factors on DT adoption provides a rationale for integrating the two theories (Bevilacqua *et al.*, 2025).

2.2. Factors Influencing DT in SMEs

2.2.1. DT Adoption in SMEs

Digital transformation is considered the third stage in an evolutionary process that follows digitization and digitalization (Dörr *et al.*, 2023). Verhoef *et al.* (2021) argue that DT is multidisciplinary and involves changes in strategy, organization, information technology, supply chains, and marketing. It is also defined as a significant organizational change, driven by new technologies and business models (Appio *et al.*, 2021; Rojas-Segura *et al.*, 2023). Adopting DT can enable SMEs to enhance revenue growth, improve cost efficiency, and increase sustainability (Costa Melo *et al.*, 2023), making it critical for maintaining competitiveness in the digital age (Lafuente *et al.*, 2022).

2.2.2. Technological Context and Perceived Barriers

Researchers agree that digital technology is essential for advancing DT in SMEs (Merín-Rodríguez *et al.*, 2024). SMEs require solid digital infrastructure to support the DT process (Nambisan *et al.*, 2017; Hu *et al.*, 2024). Various technologies can be adopted to achieve this, including artificial intelligence (AI), big data, cloud computing, blockchain, social media, e-commerce, radio frequency identification (RFID), digital platforms, and smart home and manufacturing solutions (Hanelt *et al.*, 2021). Using these technologies helps to manage changes in value proposition, business model, and product innovation.

However, DT also introduces risks for SMEs, including a shortage of skilled digital labor and limited expertise, which hinder technology adoption (Müller *et al.*, 2024). Escribá-Carda *et al.* (2024) identify the following specific barriers to DT adoption in SMEs: resource constraints; a lack of strategic focus on digitalization; bureaucratic processes; insufficient commitment from senior management; data security issues; a lack of technical knowledge and skills; resistance to change; unsuitable managerial and cultural approaches; and context-related barriers.

2.2.3. Organizational Context (Top Management Support, Digital Strategy, Competencies and Skills, and Performance)

Many studies emphasize the pivotal role of TMS in the implementation of digital strategies (Hess *et al.*, 2016; Luo & Yu, 2022). In SMEs, this often signifies the support of the owner-manager, who must orchestrate organizational change in a digital context (Moeuf *et al.*, 2019). De Mattos *et al.* (2023) also argue that DT in SMEs is primarily related to the vision and support of top management, as they directly influence the formulation and implementation of DT strategy.

Digital strategy is recognized as one of the most important internal factors driving firm digitalization (Kane *et al.*, 2015; Hu *et al.*, 2024). Previous research has found that effective digital strategy and DT initiatives lead to improved firm performance (Escríbá-Carda *et al.*, 2024). Lafuente and Sallan (2024) found a positive correlation between the use

of the Internet of Things (IoT) and AI, and four dimensions of solution-based strategy: customer embeddedness, offer integratedness, operational adaptiveness, and networkedness.

Using digital technologies and DT is linked to developing new skills and competencies. According to [Lafuente et al. \(2023\)](#), digital competencies facilitate optimal vertical and horizontal co-innovation practices. [Vaillant et al. \(2025\)](#) found that cooperation enabled by AI platforms leads to the development of three strategic situating capabilities: grounding, which facilitates learning and adaptation to specific contexts; bounding, which prevents knowledge expropriation and ensures clear roles and responsibilities; and recasting, which enables dynamic adaptation to evolving conditions. Therefore, combining various digital technologies and skills is essential for DT.

Studies reveal that adopting digital technology and DT has a positive effect on firm performance ([Costa Melo et al., 2023](#); [Barba-Sánchez et al., 2024](#)). The application of new digital technologies can result in new products and services, new customer experiences, and added value ([Lafuente et al., 2023](#)).

2.2.4. Environmental Context

Environmental factors refer to pressures from competitors, suppliers, customers, and government regulations ([Escribá-Carda et al., 2024](#)). According to [Hu et al. \(2024\)](#), market competition is one of the most influential external factors affecting SMEs' DT adoption — the more firms that adopt DT, the greater the pressure on others to follow suit. Digital tools enable SMEs to integrate customer feedback and respond to new requirements ([Dörr et al., 2023](#)). Government support relates to specific policies aimed at fostering DT in SMEs ([Faiz et al., 2024](#); [Hu et al., 2024](#)). Governments can help SMEs to overcome barriers by providing initial funding ([Lafuente et al., 2022](#)) or by implementing policies relating to financing, taxes, and partnerships ([Escribá-Carda et al., 2024](#)).

2.3. Characteristics of Managers and Firms

2.3.1. Characteristics of SME Managers

The combination of TOE and UET highlights that firms operating under the same environmental conditions may differ in their strategic responses to DT due to the individual differences of their managers ([Li & Shao, 2023](#)). Although incomplete and imprecise, managers' characteristics serve as valid proxies for the cognitive frames they use to interpret strategic situations ([Hambrick, 2007](#)). In this way, managerial characteristics moderate the influence of TOE factors on DT adoption by shaping how environmental pressures or technological development are perceived and responded to ([Religia et al., 2025](#)).

Managers' characteristics can be grouped into individual (age and gender) and human capital (education and work experience) characteristics (e.g., [Bayon et al., 2016](#))¹. In line with the UET, [Centobelli et al. \(2022\)](#) demonstrate that the attitudes of SME managers towards the adoption of technology are influenced by individual factors such as age and gender, as well as human capital factors such as work experience and education.

[Eze et al. \(2023\)](#) found that the age of entrepreneurs was significantly and positively related to the adoption of mobile marketing technology (MMT). [Centobelli et al. \(2022\)](#) also found that the prevalence of young founders (under 35 years old) enhances the adoption of inter-organizational infrastructures. However, other researchers argue that past experience and savings encourage investment in digitalization ([Ferreira et al., 2019](#)).

Regarding gender differences, some studies show that male enterprise owners are more likely to adopt technology ([Quaye et al., 2024](#)), while others find no significant gender-based differences in DT ([Sharma et al., 2023](#)).

¹ We would like to thank the anonymous reviewer for suggesting this approach to both managers' and firms' characteristics.

Eze et al. (2023) found that the work experience and education of SME managers played a significant role in MMT adoption. Entrepreneurs with higher levels of education are more likely to use digital technologies (Quaye et al., 2024). More educated SME managers may have better access to resources, which can accelerate digitalization (Clemente-Almendros et al., 2024). Therefore, firms with younger and better-educated managers (UET traits) are better positioned to provide greater managerial support (a TOE organizational factor) and adopt DT faster.

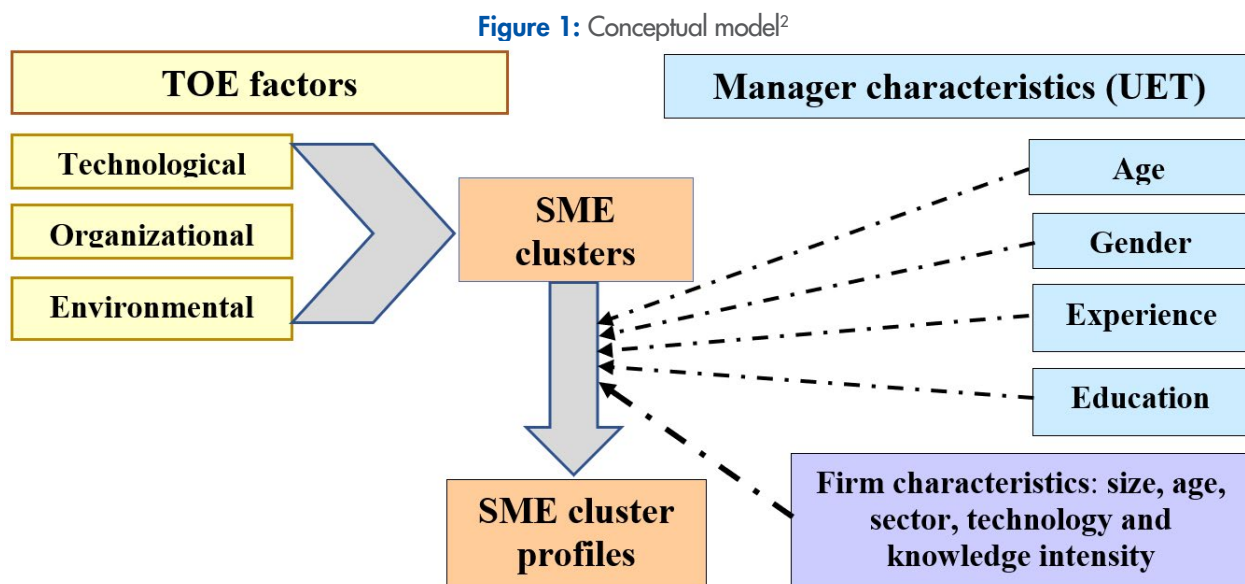
2.3.2. Characteristics of SMEs

The firms' characteristics can also be seen as individual profiles (size and age) and industry traits (manufacturing vs services, high vs. low technology). Previous studies find that not all SMEs have the capacity to undertake DT, as smaller firms are less likely to introduce new digital solutions (OECD, 2021). Larger firms tend to innovate more efficiently (Lafuente et al., 2023), and medium-sized firms are more likely to adopt DT than smaller ones (Holl & Rama, 2024).

Holl and Rama (2024) report that older firms are less likely to adopt DT, although this relationship is not linear. Centobelli et al. (2022) also indicate significant differences between recently established start-ups and older firms.

Escribá-Carda et al. (2024) demonstrate that a company's level of digitalization is influenced by its sector. According to Holl and Rama (2024), manufacturing firms are less likely to adopt DT than service firms. Other studies reveal that SMEs in the manufacturing and service industries exhibit distinct characteristics that impact their DT processes (Holl & Rama, 2024; Xie et al., 2023). In knowledge-intensive sectors, firms use all types of technologies more intensively, while adoption rates in other sectors are much lower (OECD, 2021). Xie et al (2023) confirm that high-tech SMEs are more willing to invest in DT. Lafuente et al (2023), meanwhile, note that knowledge-intensive business services demonstrate greater innovation efficiency.

Therefore, identifying the socio-demographic profiles of different SME groups in relation to DT factors is important for the effective planning of digitalization support programmes. Based on the literature review and the integrated TOE-UET framework, the conceptual model of this study is presented in Figure 1.



² The arrows from TOE factors to SME clusters and from the SME clusters to their profiles in Figure 1 do not reflect causality but show the relationships described in the clustering literature. The arrows from both manager and firm characteristics reveal their moderating role on these relationships.

We therefore hypothesize:

H1. Managerial characteristics indirectly moderate the effects of TOE factors on SME cluster profiles related to DT.

H2. Firm characteristics indirectly moderate the effects of TOE factors on SME cluster profiles related to DT.

3. Materials and Methods

3.1. Sample and Data Collection

This study is based on data from a larger research project on DT of SMEs in Bulgaria³. The sample was stratified by firm size (micro, small, and medium-sized enterprises) and technological intensity (four strata based on NACE Rev. 2). Data were collected by the research agency Noema (noema.bg) via computer-assisted personal interviews during the period September–December 2023. From this database, companies where the sole respondent was an owner or partner were selected (n = 338).

Interviewing a single manager per SME raised concerns about common method variance (CMV). To address this issue, we conducted Harman's one-factor test (Podsakoff et al., 2003) by incorporating all construct items into a principal component factor analysis. The total variance extracted by a single factor was 35.824%, indicating that CMV was not a significant issue in this sample.

3.2. Variable Measurement

The questionnaire consisted of seven multi-item sections, totaling 35 questions. All items were measured using a 5-point Likert scale, ranging from 1 ('completely disagree' or 'not at all important') to 5 ('completely agree' or 'very important'). These items were adopted and adapted from previous research to align with the main dimensions of the TOE framework. The external factors were adapted from the work of Luo and Yu (2022) and De Mattos et al. (2023), the digital strategy items were sourced from the work of Leischnig et al. (2017), and the perceived barriers items were taken from the work of Müller et al. (2024). Items measuring the use of digital technology were adapted from Hanelt et al (2021) and the three items measuring DT adoption were adopted from Nwankpa and Roumani (2016). Firm performance indicators were adapted from Barba-Sánchez et al. (2024) and indicators of government support were adapted from the OECD (2021). Control variables, including firm size and age, were adopted from Eller et al. (2020), while manager characteristics (age, experience, education, and gender) were adapted from Eze et al. (2011).

4. Results

4.1. Descriptive Statistics

In terms of ownership, 99.7% of the SMEs investigated are private, and 98.8% are independent. In terms of size, micro-enterprises (0–9 employees) predominate at 66.0%, followed by small enterprises (10–49 employees) at 24.3%, and medium-sized enterprises (50–249 employees) at 9.8%. The sample is distributed across the following sectors: services (41.2%), manufacturing (32.6%), retail and wholesale trade (24.2%), and construction (2.1%). 13.3% of the SMEs operate in high and medium-high technology industries; 22.2% - in medium-low and low-tech industries; 21.9% - in knowledge-

³ The present study is under the project "Digitalisation of SMEs", headed by Prof DSc Desislava Yordanova within the greater SUMMIT project of the Sofia University "St Kliment Ohridski" (<https://summit.uni-sofia.bg>).

intensive services; and 42,6% - in low-knowledge-intensive services. The largest proportion of SMEs are aged between 7-15 years (28.4%), followed by those aged 21-30 years (26.0%), 16-20 years (18.9%), 0-6 years (18.3%), and over 30 years (8.3%).

All of the respondents are either owners or partners. Of these, 187 (55.3%) are male and 151 (44.7%) are female. The respondents with a master's degree predominate at 43.2%, followed by those with a secondary education at 31.4%. The largest proportion of respondents is aged 46–55 (37.0%), followed by those over 55 (36.1%). The majority of respondents have worked at their firm for more than 15 years (46.7%), followed by those with 6–10 years' work experience (21.3%).

4.2. Factor Analysis Results

An exploratory factor analysis (EFA) with Varimax rotation was conducted. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.935, with DF = 595, an approximate Chi-Square value of 10,625.279 and a significance level of 0.000. All of the variables used had a communality greater than 0.5, and the total variance explained was 78.303%. The EFA yielded seven factors. All item-to-factor loadings were above 0.7 and all factors demonstrated Cronbach's alpha values greater than 0.7 (Table 1), indicating strong internal consistency.

Table 1: Results of EFA

Factors	F1. Performance	F2. Digital strategy	F3. Perceived barriers	F4. Government support	F5. Environmental factors	F6. Technology usage	F7. DT adoption
Number of items	6	6	6	5	5	4	3
Initial Eigenvalues	12.538	4.710	2.872	2.581	2.130	1.342	1.232
% of Variance	35.824	13.458	8.205	7.374	6.086	3.835	3.521
Cronbach's alpha	0.962	0.961	0.925	0.941	0.931	0.763	0.876
Total variance explained	78.303%						

The factors are not strongly correlated; the maximum significant correlation is 0.683, between Environmental Factors and Digital Strategy. The adoption of DT is significantly and positively correlated with all the other factors, while its correlation with Perceived Barriers is negative. These values indicate good consistency of the measures.

The first factor, Performance, reflects the firm's financial and non-financial achievements over the past three years. Studies show that DT can enhance firm performance by improving quality, reducing costs, and promoting innovation (Eller et al., 2020; Vaillant & Lafuente, 2024). According to Holl and Rama (2024), firms that had already adopted digital technologies were better equipped to cope with challenges such as the pandemic.

The second factor, Digital Strategy, is considered one of the most critical internal factors for implementing digitalization in firms (Escribá-Carda et al., 2024). The success of DT initiatives depends not only on the use of technology, but also on the presence of an effective digital strategy (Kane et al., 2015; Hess et al., 2016).

The third factor measures Perceived Barriers to digitalization. SMEs' ability to adopt new technologies is constrained by their small size and limited financial and human resources (Escribá-Carda et al., 2024). However, DT can also be associated with negative outcomes, such as employee resistance, inertia or even a decline in performance, due to the high investment required (Merín-Rodríguez et al., 2024).

The fourth factor, Government Support for SME Digitalisation, emerges as a distinct environmental factor. This support manifests as financial subsidies and programs designed to stimulate DT in SMEs (OECD, 2021). Researchers emphasize the government's essential role in providing support to small businesses through targeted programs and initiatives (Lafuente et al., 2022; Hu et al., 2024).

The fifth factor is Environmental Factors, which exert pressure on SMEs to digitalize. This pressure originates from competitors, customers, suppliers, the development of digital technologies, and the business environment as a whole (Faiz et al., 2024; Escribá-Carda et al., 2024).

The sixth factor relates to the use of new technologies, specifically Blockchain, RFID, IoT, and AI. These digital technologies have been well documented in other studies (Hanelt et al., 2021).

The seventh factor, DT Adoption, measures the extent to which a firm integrates digital technologies and manages business processes based on them. DT is recognized as a critical component in the successful development of companies, regardless of their size (Lafuente et al., 2022; Barragán & Becker, 2025).

4.3. Cluster Analysis Results

For the cluster analysis, the seven factors were transformed into new composite measures. These were calculated as the sum of the values of their constitutive items, divided by the maximum possible sum and multiplied by 100. Two additional factors (TMS and Employee Skills) were calculated in a similar way to assess the predictive validity of the cluster solution. The Caliński-Harabasz (CH) index (1974) was applied to determine the optimal number of clusters for 2, 3, 4, and 5-cluster solutions. The 5-cluster solution was discarded as one cluster contained fewer than 10% of cases. We proceeded with the three-cluster solution, which had the second-highest CH index after the two-cluster solution. In addition, NbClust package in RStudio was used to determine the number of clusters (Charrad et al., 2014). According to the majority rule, the optimal number of clusters is three, as suggested by 12 indices.

K-means cluster analysis resulted in cluster sizes of 67, 163, and 108 cases, respectively. The differences in the variable means across the three clusters are statistically significant (Table 2).

Table 2: Variables means by non-hierarchical three cluster solution (N = 338)

Composite variable (factor)	Variable means by cluster			F	Sig.
	1	2	3		
F1. Performance	91.1940	80.6953	59.2593	108.128	.000
F2. Digital strategy	83.1841	65.0920	38.3333	213.441	.000
F3. Perceived barriers	30.6965	57.0757	48.1481	49.052	.000
F4. Government support	75.7015	65.3988	44.2963	83.416	.000
F5. Environmental factors	82.0896	71.8528	36.5926	307.367	.000
F6. Technology usage	38.7313	32.9141	24.3981	21.670	.000
F7. DT adoption	63.4826	25.5215	22.0370	270.744	.000
Size of the cluster	67/19.82%	163/48.22%	108/31.95%		

A Regularized Discriminant Analysis (RDA) was performed in RStudio to validate the three-cluster solution, since the data were not normally distributed and the covariance matrices were unequal. This method estimates covariance using the parameters gamma γ and lambda λ (both between 0 and 1), providing a compromise between linear and quadratic discriminant analyses (Hastie et al., 2009). Training the model with a 65:35 training-to-test sample ratio optimized the regularization parameters at $\lambda = 0.950$ and $\gamma = 0.258$. These values (λ close to 1 and γ close to 0) indicate that the RDA function reduces the covariance closer to a common matrix, similar to a Linear Discriminant Analysis function. The computed RDA model accuracy was 0.949, indicating that the seven independent factors discriminate well between the three clusters and can effectively predict cluster membership.

The predictive validity of the cluster solution was further assessed using two compound measures (TMS and Employee Skills). ANOVA results confirmed that the cluster solution predicts other SME characteristics: Cluster 1 had the highest scores on these variables, while Cluster 3 had the lowest.

The final cluster solution was profiled using eight demographic characteristics of both firms and owners/partners: (1) firm size, (2) manufacturing versus services, (3) sector by technological and knowledge intensity, (4) the manager's experience in the firm (in years), (5) the manager's level of education, (6) gender, (7) firm age, and (8) the manager's age. To examine the effects of TMS and Employee Skills, these factors were transformed into binary variables (1 = weak/low; 2 = strong/high). Relationships were tested using cross-tabulation analysis and chi-square values (Table 3).

Chi-square values were significant for all variables except the age of the firm and the age and gender of the owner/manager (Table 3).

The three-cluster solution reveals a clear distinction among the investigated SMEs with regard to DT factors, with two distinct clusters (Clusters 1 and 3). Cluster 1 comprises 67 SMEs (19.82%) and has the highest scores for all factors except Perceived Barriers. This cluster mainly consists of small and medium-sized enterprises (52.2%), primarily from the manufacturing sector (56.7%), and from high/medium-high technology industries and knowledge-intensive services (61.2%). The owners/partners in this cluster predominantly have extensive work experience (74.6% have worked for over 11 years) and hold master's degrees (53.7%). They provide higher TMS (98.5%) and have employees with higher digital skills (98.5%).

Cluster 3 includes 108 SMEs (31.95%) and shows the opposite pattern, with the lowest values on all factors except Perceived Barriers. This cluster is predominantly composed of micro-enterprises (76.9%), in service sectors (80.6%), especially low-knowledge-intensive services (70.4%). The owners/partners in this cluster have less work experience (38.9% have 10 or fewer years) and mostly have secondary-level qualifications (50.9%). They demonstrate weak TMS (85.2%) and employ individuals with limited digital proficiency (83.3%).

Cluster 2 comprises 163 SMEs (48.22%) and represents an intermediate group, scoring between Clusters 1 and 3 on most variables, but reporting the highest level of Perceived Barriers.

Therefore, Cluster 1 includes SMEs that are the most advanced in terms of DT, representing digital leaders. In contrast, Cluster 3 consists of SMEs that are the least advanced. Cluster 2 scores closer to Cluster 1 on other factors, except for Perceived Barriers and DT adoption. This typology bears some similarity to the four-group taxonomy of Centobelli *et al* (2022), although the number of clusters differs.

The data shows that the TOE factors alone are not sufficient to explain the differences between the identified clusters, while the inclusion of key demographic characteristics of owners/partners (UET) and firms allows understanding these differences. These characteristics act as a filter that translates/moderates the influence of the TOE factors. The effects of firm characteristics are similar. More advanced DT is observed in larger SMEs with more resources, especially from high-tech industries and knowledge-intensive services.

These findings partially support H1, demonstrating that SMEs with more experienced and educated managers, greater management support, and higher digital skills are more advanced in DT. Meanwhile, the age and gender of the manager have no significant effect.

H2 is also partially supported, as firm size, sector, and technology and knowledge intensity moderate the impact of TOE factors on DT, while firm age has no significant moderating effect.

Table 3: Cross-classification of additional variables and three clusters (%)

		Clusters			Total
		1 (67)	2 (163)	3 (108)	(338)
Firm size	0-9 employees	47.8	66.3	76.9	66.0
	10-49 employees	34.3	23.3	19.4	24.3
	50-249 employees	17.9	10.4	3.7	9.8
Total ($X^2 = 17,891$; $df = 4$, Asympt.Sig.=0.001)			100.0	100.0	100.0
Firm age	Young (0-6 years)	5	35	22	62
	Established (7-15 years)	18	47	31	96
	Experienced (16-20 years)	14	27	23	64
	Mature (21-30 years)	26	40	22	88
	Adult (over 30 years)	4	14	10	28
Not significant					
Sector	Manufacturing	56.7	37.4	19.4	35.5
	Services	43.3	62.6	80.6	64.5
Total ($X^2 = 25,592$; $df = 2$, Asympt.Sig.=0.000)			100.0	100.0	100.0
Firms by technology/knowledge intensity	High and medium-high technology industries	31.3	13.5	1.9	13.3
	Medium-low and low-tech industries	25.4	23.9	17.6	22.2
	Knowledge-intensive services	29.9	26.4	10.2	21.9
	Low-knowledge-intensive services	13.4	36.2	70.4	42.6
Total ($X^2 = 73,272$; $df = 6$, Asympt.Sig.=0.000)			100.0	100.0	100.0
Owner/partner work experience in the current firm	Under 1 year		2.5	0.9	1.5
	1-5 years		14.1	13.9	11.2
	6-10 years	25.4	17.8	24.1	21.3
	11-15 years	32.8	16.0	15.7	19.2
	Over 15 years	41.8	49.7	45.4	46.7
Total ($X^2 = 22,256$; $df = 8$, Asympt.Sig.=0.004)			100.0	100.0	100.0
Owner/partner education	Secondary/Specialized Secondary	14.9	25.2	50.9	31.4
	Bachelor's Degree	29.9	18.4	29.6	24.3
	Master's Degree	53.7	55.2	18.5	43.2
	Doctoral Degree	1.5	1.2	0.9	1.2
Total ($X^2 = 47,922$; $df = 6$, Asympt.Sig.=0.000)			100.0	100.0	100.0
Owner/partner gender	Male	62.7	49.1	60.2	55.3
	Female	37.3	50.9	39.8	44.7
Not significant			100.0	100.0	100.0
Owner/partner age	Up to 25 years	0	2	0	2
	26-35 years	2	15	10	27
	36-45 years	10	29	23	62
	46-55 years	33	54	38	125
	Over 55 years	22	63	37	122
Not significant					
Top Management Support	Weak	1.5	22.7	85.2	38.5
	Strong	98.5	77.3	14.8	61.5
$X^2 = 155.413$; Asympt.Sig. (2-sided) = 0.000					
Employee digital skills	Low	1.5%	27.0%	83.3%	39.9%
	High	98.5%	73.0%	16.7%	60.1%
$X^2 = 137.452$; Asympt.Sig. (2-sided) = 0.000					

5. Discussion

Integrating the TOE model with the UET enhances the understanding of SME DT by combining the influence of managerial-level characteristics (UET) with broader firm-level and external factors (TOE). This integrated approach helps to explain why, under similar external and internal conditions, some SMEs are more successful in DT than others. According to the UET, the mindset and expertise of managers shape their perception and interpretation of the opportunities and challenges presented by TOE factors (Eze *et al.*, 2023). These managers' characteristics are a key internal factor that moderates the effect of TOE factors on DT across different SME groups (Clemente-Almendros *et al.*, 2024; Li & Shao, 2023). Other studies confirm that top managers' experience has a significant positive influence on technology adoption (Ferreira *et al.*, 2019). The present data also show that 75% of owners/partners in the first cluster have extensive work experience, compared to 61% in the third cluster.

Similarly, a managers' digital literacy, which is related to their level of education, influences how effectively they allocate resources towards DT, thereby moderating the impact of TOE factors (Li & Shao, 2023). In terms of education, only 15% of owners/partners in the first, most advanced cluster have a secondary education, compared to 51% in the third, most lagging cluster.

Female-led SMEs are somewhat overrepresented in the third cluster (40%), while male-led SMEs predominate in the first cluster (63%). However, this difference is not statistically significant. These data support the findings of other studies, which also found no significant gender differences in SME digitalization (Centobelli *et al.*, 2022; Sharma *et al.*, 2023).

Contrary to some previous results (Eze *et al.*, 2023; Plečko *et al.*, 2023), the data show that managers' age does not affect DT. Therefore, the present results find that the managerial human capital (experience and education) is more important for DT in SMEs, compared to their individual profiles (age and gender).

Additionally, the first cluster comprises mainly SMEs with strong TMS and high digital skills, while the third cluster comprises mainly SMEs with weak TMS and low digital skills. Many researchers agree that TMS and digital skills are prerequisites for digital innovation (Lafuente *et al.*, 2023; Vaillant *et al.*, 2025).

The present results are consistent with other studies indicating that larger SMEs have greater resources, enabling them to use digital technology to a greater extent than smaller firms (Centobelli *et al.*, 2022; Holl & Rama, 2024).

These results correspond to the differences in digitalization identified between SMEs in high-tech and low-tech sectors (OECD, 2021). Consistent with the findings of Lafuente *et al.* (2023) and Jie *et al.* (2025), the present data reveal that 61% of SMEs in the first cluster operate in high/medium-high technology industries and knowledge-intensive services, whereas 70% of SMEs in the third cluster operate in low-knowledge-intensive services. Therefore, the firm's size and the firm's industry characteristics are more decisive factors for DT compared to the firm's age.

Most SMEs in the first cluster are from the manufacturing sector (57%), whereas the third cluster is dominated by SMEs from the service sector (81%). These data corroborate the findings of Xie *et al.* (2023), who discovered that manufacturing firms implement DT more extensively. However, they contradict the findings of Holl and Rama (2024), who reported that manufacturing firms were less likely to adopt DT than service firms.

In summary, both the managerial human capital and the firm's size and industry characteristics are needed to explain the SMEs heterogeneity regarding DT (Lafuente *et al.*, 2010; Clemente-Almendros *et al.*, 2024). On the one hand, the managers' work experience and education (UET traits) moderate the effects of the TOE factors in terms of managerial support, digital strategy, resource allocation, and provision of digital training for employees. On the other hand, the firm size, industry, and technological and knowledge intensity also moderate the influence of the TOE factors in terms of available resources and the technological development.

6. Conclusions and future research

The study aimed to identify distinct groups of SMEs based on DT factors and demographic characteristics of managers and firms. To this end, factor and cluster analyses were conducted. The factor analysis identified seven factors, which were then used in the cluster analysis. The three-cluster solution, profiled using demographic indicators, revealed clear distinctions between SMEs in relation to DT factors. The results showed that firm size, manufacturing, high-technology and knowledge-intensive sectors, TMS, employee skills, and managers' work experience and education were all positively related to SMEs' DT advancement. No significant differences were found based on firm or manager age or gender.

The theoretical contribution of this study lies in integrating the TOE model with the UET. While the TOE framework identifies key drivers for DT, managerial characteristics act as crucial moderators, shaping how these factors are understood, utilized, and applied to DT (Bayon et al., 2016; Li & Shao, 2023). The data demonstrate that a manager's human capital (education and work experience), combined with TMS and higher digital skills, modifies the relationship between external, organizational, and technological factors and a firm's capacity to adopt digital technologies. The interaction between TOE factors and managerial characteristics provides rationale for the integration of the two theories (Becos & Chari, 2025) and suggests a new direction for further studies using an integrated approach.

Integrating these theories also provides SMEs and policymakers with specific insights. For SME owners in all sectors, the implication is that they need to invest in the digital literacy and expertise of their managers, and/or hire personnel with up-to-date digital qualifications. This will enable SME managers to make strategic decisions regarding the most suitable technologies for their objectives and secure adequate investment in infrastructure, talent acquisition, and skill development (Lafuente et al., 2021).

Successful DT also assumes appropriate training in the use of digital technologies. Training can equip employees with the expertise to use new technologies, while digital mentoring can provide personalized support for DT implementation (Moeuf et al., 2019). The present results may encourage SME managers to invest in digital literacy and foster a culture that supports learning.

Vaillant (2022) and Lafuente et al. (2023) argue that a country's national innovation system creates conditions that influence local SMEs' capacity to generate, produce, and diffuse innovation. However, SMEs often lack the time and resources to foster their employees' digital skills. Therefore, they need support from the overall business ecosystem. Governments' financial support can help SMEs afford the initial costs of adopting new technologies (OECD, 2021; Lafuente et al., 2022). The results of this study suggest that the government should provide tailored assistance to specific groups of SMEs.

This study has several limitations. Firstly, the use of a non-representative sample means that the findings cannot be generalized. It is based on cross-sectional data and does not track changes in the DT of the investigated firms over time. Secondly, while the integrated TOE-UET model is robust, it may not capture all relevant variables, such as the firm's absorptive capacity and the role of external consultants. Thirdly, the technological context was operationalized through a specific set of technologies, potentially omitting other relevant digital tools. Finally, the study only focuses on SMEs from one country with its specific national ecosystem, which may differ from that of other countries. Heterogeneity of SMEs regarding DT is likely to vary across countries. Therefore, further research using longitudinal, multi-source data and more direct psychological measures is needed to understand the specific conditions under which SMEs can accelerate their DT.

Acknowledgment

This study is financed by the European Union-Next Generation EU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project No BG-RRP-2.004-0008.

References

- Appio, F. P., Frattini, F., Petruzzelli, A. M., & Neirotti, P. (2021). Digital transformation and innovation management: A synthesis of existing research and an agenda for future studies. *Journal of Product Innovation Management*, 38(1), 4-20. <https://doi.org/10.1111/jpim.12562>
- Awa, H. O., Ukoha, O., & Igwe, S. R. (2017). Revisiting technology-organization-environment (T-O-E) theory for enriched applicability. *The Bottom Line*, 30(01), 2-22. <https://doi.org/10.1108/BL-12-2016-0044>
- Barba-Sánchez, V., Meseguer-Martínez, A., Gouveia-Rodrigues, R., & Raposo, M. L. (2024). Effects of digital transformation on firm performance: The role of IT capabilities and digital orientation. *Heliyon*, 10(6), e27725. <https://doi.org/10.1016/j.heliyon.2024.e27725>
- Barragan, E., & Becker, K. F.S.R. (2025). Keeping pace with the digital transformation — exploring the digital orientation of SMEs. *Small Business Economics*, 64, 1361-1385. <https://doi.org/10.1007/s11187-024-00947-7>
- Bayon, M. C., Lafuente, E., & Vaillant, Y. (2016). Human capital and the decision to exploit innovative opportunity. *Management Decision*, 54(7), 1615-1632. <https://doi.org/10.1108/MD-04-2015-0130>
- Bekos, G., & Chari, S. (2025). *Upper echelons theory: A review*. TheoryHub book. <https://open.ncl.ac.uk/>
- Bevilacqua, S., Masárová, J., Perotti, F.A., & Ferraris, A. (2025). Enhancing top managers' leadership with artificial intelligence: insights from a systematic literature review. *Revue of Managerial Science*, 19, 2899-2935. <https://doi.org/10.1007/s11846-025-00836-7>
- Caliński, T., & Harabasz, J. (1974). A dendrite method for cluster analysis. *Communications in Statistics*, 3(1), 1-27. <https://doi.org/10.1080/03610927408827101>
- Centobelli, P., Cerchione, R., Esposito, E., Passaro, R., & Quinto, I. (2022). The undigital behavior of innovative startups: empirical evidence and taxonomy of digital innovation strategies. *International Journal of Entrepreneurial Behavior & Research*, 28(9), 219-241. <https://doi.org/10.1108/IJEER-08-2021-0626>
- Charrad, M., Ghazzali, N., Boiteau, V., & Niknafs, A. (2014). NbClust: An R package for determining the relevant number of clusters in a data set. *Journal of Statistical Software*, 61(6), 1-36. <https://doi.org/10.18637/jss.v061.i06>
- Clemente-Almendros, J.A., Nicoara-Popescu, D., & Pastor-Sanz, I. (2024). Digital transformation in SMEs: Understanding its determinants and size heterogeneity. *Technology in Society*, 77, 102483. <https://doi.org/10.1016/j.techsoc.2024.102483>
- Costa Melo D.L., Queiroz, G.A., Alves Junior, P.N., Sousa, T.B., Yushimito, W.F., & Pereira J. (2023). Sustainable digital transformation in small and medium enterprises (SMEs): A review on performance. *Heliyon*, 9(3), e13908. <https://doi.org/10.1016/j.heliyon.2023.e13908>
- De Mattos, C. S., Pellegrini, G., Hagelaar, G., & Dolfisma, W. (2023). Systematic literature review on technological transformation in SMEs: a transformation encompassing technology assimilation and business model innovation. *Management Review Quarterly*, 74, 1057-1095. <https://doi.org/10.1007/s11301-023-00327-7>
- Dörr, L., Fliege, K., Lehmann, C., Kanbach, D. K., & Kraus, S. (2023). A taxonomy on influencing factors towards digital transformation in SMEs. *Journal of Small Business Strategy*, 33(1), 53-69. <https://doi.org/10.53703/001c.66283>
- Eller, R., Alford, P., Kallmünzer, A., & Peters, M. (2020). Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization. *Journal of Business Research*, 112, 119-127. <https://doi.org/10.1016/j.jbusres.2020.03.004>
- Escribá-Carda, N., Redondo-Cano, A., & Escribá-Moreno, M. Ángeles. (2024). Firms' digital transformation and e-human resource management. A qualitative approach. *TEC Empresarial*, 18(3), 103-128. <https://doi.org/10.18845/te.v18i3.7289>

- European Commission. (2024, August 7). The Digital Economy and Society Index (DESI). <https://digital-strategy.ec.europa.eu/en/policies/desi>
- Eze, S.C., Okoye, J.C., Nebo, O.J., Ohakwe, S.N., Chukwuemeka, E., & Anazodo, R. (2011). Using the characteristics of small business managers to understand information technology (IT) adoption in Nigeria. *International Journal of Business and Social Science*, 2(13), 82-90. <https://www.researchgate.net/publication/322736379>
- Eze, S.C., Awa, H.O., Chinedu-Eze, V.C., & Eniola, A. (2023). Can location factors moderate the effects of the demographic composition of SME's owner managers on the rate of mobile marketing technology (MMT) adoption? *PLoS ONE*, 18(8), e0289734. <https://doi.org/10.1371/journal.pone.0289734>
- Faiz, F., Le, V., & Masli, E.K. (2024). Determinants of digital technology adoption in innovative SMEs. *Journal of Innovation & Knowledge*, 9(4), 100610. <https://doi.org/10.1016/j.jik.2024.100610>
- Ferreira, J. J. M., Fernandes, C. I., & Ferreira, F. A. F (2019). To be or not to be digital, that is the question: Firm innovation and performance, *Journal of Business Research*, 101, 583-590. <https://doi.org/10.1016/j.jbusres.2018.11.013>
- Hambrick, D. C. (2007). Upper echelons theory: an update. *Academy of Management Review*, 32(2), 334-343. <https://doi.org/10.5465/amr.2007.24345254>
- Hambrick, D. C., & Mason, P. A. (1984). Upper echelons – The organization as a reflection of its top managers, *Academy of Management Review*, 9(2), 193-206. <https://doi.org/10.2307/258434>
- Hanelt, A., Bohnsack, R., Marz, D., & Marante, C.A. (2021). A systematic review of the literature on digital transformation: insights and implications for strategy and organizational change. *Journal of Management Studies*, 58(5), 1159-1197. <https://doi.org/10.1111/joms.12639>
- Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The elements of statistical learning: Data mining, inference, and prediction* (2nd ed.). Springer
- Hess, T., Matt, C., Benlian, A., & Wiesboeck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, 15(2), 123-139
- Holl, A., & Rama, R. (2024). SME digital transformation and the COVID-19 pandemic: a case study of a hard-hit metropolitan area. *Science and Public Policy*, 51(6), 1212-1226. <https://doi.org/10.1093/scipol/scae023>
- Hu, Y., Pan, Y., Yu, M., & Chen, P. (2024). Navigating digital transformation and knowledge structures: Insights for small and medium-sized enterprises. *Journal of Knowledge Economy*, 15, 16311-16344. <https://doi.org/10.1007/s13132-024-01754-x>
- Jie, H., Gooi, L. M., & Lou, Y. (2025). Digital maturity, dynamic capabilities and innovation performance in high-tech SMEs. *International Review of Economics & Finance*, 99, 103971. <https://doi.org/10.1016/j.iref.2025.103971>
- Kallmuenzer, A., Mikhaylov, A., Chelaru, M., & Czakon, W. (2025). Adoption and performance outcome of digitalization in small and medium-sized enterprises. *Review of Managerial Science*, 19, 2011-2038. <https://doi.org/10.1007/s11846-024-00744-2>
- Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2015). Strategy, not technology, drives digital transformation". *MIT Sloan Management Review*, 14, 1-25.
- Lafuente, E., Acs, Z. J., & Szerb, L. (2022). Analysis of the digital platform economy around the world: A network DEA model for identifying policy priorities. *Journal of Small Business Management*, 62(2), 847-891. <https://doi.org/10.1080/00472778.2022.2100895>
- Lafuente, E., Alonso-Ubieta, S., Leiva, J. C., & Mora-Esquivel, R. (2021). Strategic priorities and competitiveness of businesses operating in different entrepreneurial ecosystems: a benefit of the doubt (BOD) analysis. *International Journal of Entrepreneurial Behavior & Research*, 27(5), 1351-1377. <https://doi.org/10.1108/IJEBr-06-2020-0425>

- Lafuente, E., Araya, M., & Leiva, J. C. (2022). Assessment of local competitiveness: A composite indicator analysis of Costa Rican counties using the 'Benefit of the Doubt' model. *Socio-Economic Planning Sciences*, *81*, 100864. <https://doi.org/10.1016/j.seps.2020.100864>
- Lafuente, E., Bayo-Moriones, A., & García-Cestona, M. (2010). ISO-9000 certification and ownership structure: Effects upon firm performance. *British Journal of Management*, *21*(3), 649-665. <https://doi.org/10.1111/j.1467-8551.2009.00660.x>
- Lafuente, E., & Sallan, J. M. (2024). Digitally powered solution delivery: The use of IoT and AI for transitioning towards a solution business model. *International Journal of Production Economics*, *277*, 109383. <https://doi.org/10.1016/j.ijpe.2024.109383>
- Lafuente, E., Vaillant, Y., & Rabetino, R. (2023). Digital disruption of optimal co-innovation configurations. *Technovation*, *125*, 102772.
- Leischnig, A., Wöfl, S., Ivens, B., & Hein, D. (2017). From digital business strategy to market performance: insights into key concepts and processes. *ICIS 2017 Proceedings*. 20. <http://aisel.aisnet.org/icis2017/Strategy/Presentations/20>
- Li, G., & Shao, Y. (2023). How do top management team characteristics affect digital orientation? Exploring the internal driving forces of firm digitalization, *Technology in Society*, *74*, 102293. <https://doi.org/10.1016/j.techsoc.2023.102293>
- Li, L., Tang, W., Zhou, H., & Yang, S. (2024). Digitalization and firm performance: The moderating role of top management team attributes. *IEEE Transactions on Engineering Management*, *71*, 6595-6605, 2024. <https://doi.org/10.1109/TEM.2023.3242766>
- Luo, X., & Yu, S.-C. (2022). Relationship between external environment, internal conditions, and digital transformation from the perspective of synergetics. *Discrete Dynamics in Nature and Society*, 6756548. <https://doi.org/10.1155/2022/6756548>
- Merín-Rodríguez, J., Dasí, À., & Alegre, J. (2024). Digital transformation and firm performance in innovative SMEs: The mediating role of business model innovation. *Technovation*, *134*, 103027. <https://doi.org/10.1016/j.technovation.2024.103027>
- Moeuf, A., Lamouri, S., Pellerin, R., Tamayo-Giraldo, S., Tobon-Valencia, E., & Eburdy, R. (2019). Identification of critical success factors, risks and opportunities of Industry 4.0 in SMEs. *International Journal of Production Research*, *58*(5), 1384-1400. <https://doi.org/10.1080/00207543.2019.1636323>
- Müller, J. M., Islam, N., Kazantsev, N., Romanello, R., Olivera, G., Das, D., & Hamzeh, R. (2024). Barriers and enablers for industry 4.0 in SMEs: A combined integration framework. *IEEE Transactions on Engineering Management*, *99*, 1-13. <https://doi.org/10.1109/TEM.2024.3365771>
- Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: reinventing innovation management research in a digital world. *MIS Quarterly*, *41*(1), 223-238. <https://doi.org/10.25300/misq/2017/41:1.03>
- Nwankpa, J. K., & Roumani, Y. (2016). IT capability and digital transformation: A firm performance perspective. *Proceedings of the Thirty Seventh International Conference on Information Systems (ICIS 2016)*, Dublin, Ireland, 1-16. https://www.researchgate.net/publication/362751432_IT_Capability_and_Digital_Transformation_A_Firm_Performance_Perspective_Completed_Research_Paper
- OECD (2021). *The Digital Transformation of SMEs. OECD Studies on SMEs and Entrepreneurship*, OECD Publishing. <https://doi.org/10.1787/bdb9256a-en>
- Plečko, S., Tominc, P., & Širec, K. (2023). Digitalization in entrepreneurship: Unveiling the motivational and demographic influences towards sustainable digital sales strategies. *Sustainability*, *15*, 16150. <https://doi.org/10.3390/su152316150>
- Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879-903. <https://doi.org/10.1037/0021-9010.88.5.879>

- Quaye, W., Onumah, J. A., Boimah, M., & Mohammed, A. (2024). Technology adoption, competitiveness and new market access among SMEs in Ghana: What are the limiting factors? *African Journal of Science, Technology, Innovation and Development*, 16(7), 1023-1037. <https://doi.org/10.1080/20421338.2024.2414949>
- Religia, Y., Ramawati, Y., Firdausi, A.S.M., & Nainggolan, D.S. (2025). Exploring digital leadership - TOE framework in CRM adoption by SMEs in developing countries. *RAUSP Management Journal*, 60(1), 52-68. <https://doi.org/10.1108/RAUSP-09-2024-0187>
- Rojas-Segura, J., Faith-Vargas, M., & Martinez-Villavicencio, J. (2023). Conceptualizing digital transformation using semantic decomposition. *TEC Empresarial*, 17(3), 63-75. <https://doi.org/10.18845/te.v17i3.6850>
- Sharma, S., Singh, A., & Rautela, S. (2023). Social media marketing adoption by unorganised businesses in India: a technology adoption model-based approach. *International Journal of Entrepreneurship and Small Business*, 49(3), 374-394. <https://doi.org/10.1504/IJESB.2023.132526>
- Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation. Issues in organization and management series*. Lexington Books
- Vaillant, Y., & Lafuente, E. (2024). Digital versus non-digital servitization for environmental and non-financial performance benefits. *Journal of Cleaner Production*, 450, 142078. <https://doi.org/10.1016/j.jclepro.2024.142078>
- Vaillant, Y., Lafuente, E., & Vendrell-Herrero, F. (2025). AI platforms as cooperation enablers favoring the development of strategic situating capabilities within solution delivery ecosystems. *Journal of Product Innovation Management*. <https://doi.org/10.1111/jpim.12807>
- Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: a multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>
- Xie, X., Zhang, H., & Blanco, C. (2023). How organizational readiness for digital innovation shapes digital business model innovation in family businesses. *International Journal of Entrepreneurial Behavior & Research*, 29(1), 49-79. <https://doi.org/10.1108/IJEBR-03-2022-0243>