sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (4), 2024: 00–00 https://doi.org/10.18559/ebr.2024.4.1123

The effects of technology and innovation adoption on firm performance among small and medium enterprises: Evidence from Vietnam's logistics sector

Thanh Tuan Nguyen[1] Abdelghani Bekrar[2]
Thi Muoi Le[3] Abdelhakim Artiba[4]
Tarik Chargui[5] Thi Le Hoa Vo[6]
Thi Thu Huong Trinh[7]

Abstract

In Industry 4.0, technology and innovation constitute a driver for enhancing firms' performance, particularly for small and medium-sized enterprises (SMEs). Our study aims to examine whether that statement is correct for SMEs in a developing country. We developed a generic model and employed multiple regression techniques, including ordinary least-squares, robust standard errors and weighted least

Keywords

- firm performance
- innovation
- logistics
- supply chain
- technology

[1] LAMIH, LARSH (CRISS), Université Polytechnique Hauts-de-France, Le Mont Houy, 59313, Valenciennes, France, corresponding author: ThanhTuan.Nguyen@uphf.fr, https://orcid.org/0009-0007-3824-902X.

[2] LAMIH, UMR CNRS 8201, Université Polytechnique Hauts-de-France, Le Mont Houy, 59313, Valenciennes, France, Abdelghani.Bekrar@uphf.fr, https://orcid.org/0000-0003-2721-1505.

[3] LARSH (CRISS), Université Polytechnique Hauts-de-France, Les Tertiales, 59313, Valenciennes, France, Thi-Muoi.Le@uphf.fr, https://orcid.org/0009-0003-3321-4451.

[4] LAMIH, UMR CNRS 8201, Université Polytechnique Hauts-de-France, Le Mont Houy, 59313, Valenciennes, France, abdelhakim.artiba@uphf.fr, https://orcid.org/0009-0009-9997-9282.

[5] LAMIH, UMR CNRS 8201, Université Polytechnique Hauts-de-France, Le Mont Houy, 59313, Valenciennes, France, Tarik.Chargui@uphf.fr, https://orcid.org/0000-0002-8579-2566.

[6] CNRS, UMR 6211, Université de Rennes, F-3500 Rennes, France, thi-le-hoa.vo@univ-rennes.fr, https://orcid.org/0000-0001-6737-4267.

[7] School of Economics and International Business, Foreign Trade University, 91 Chua Lang Street, Dong Da District, Ha Noi City, Vietnam, ttthuhuong@ftu.edu.vn, https://orcid.org/0009-0004-0463-8383.

squares, to test this hypothesis and address heteroskedasticity. Using a micro-level dataset including 11,630 SMEs in Vietnam's logistics sector, an emerging logistics market in a developing country, our results reveals that the effects of technology on firm performance may differ depending on particular metrics of this performance. Furthermore, not all forms of innovation significantly affect SME performance. Control variables such as "firm's age", "firm's size", "state ownership", "education of the manager" and "foreign activities" also play a significant role in SME performance, underscoring the importance of both internal capabilities and external technological elements.

JEL codes: C31, D04, O30, L25.

Article received 24 January 2024, accepted 5 November 2024.

Suggested citation: Nguyen, T. T., Bekrar, A., Le, T. M., Artiba, A., Chargui, T., Vo, T. L. H., & Trinh, T. T. H. (2024). The effects of technology and innovation adoption on firm performance among small and medium enterprises: Evidence from Vietnam's logistics sector. *Economics and Business Review*, *10*(4), 0–0. https://doi.org/10.18559/ebr.2024.4.1123

Introduction

Today, the 4.0 technology revolution has permeated all economic sectors; therefore, adopting technology and innovation activities for businesses is an important and urgent requirement to improve the competitiveness of enterprises and maintain their position in the market. Thus, in recent years, there have been numerous studies on the rapid technological development as well as the use of information technology (IT) in corporate organisations (Gërguri-Rashiti et al., 2017). For small enterprises, adopting new production and management technologies is crucial to stay competitive; unfortunately, the majority of these firms tend to view these requirements in negative ways (Sevinç et al., 2018) due to significant barriers such as insufficient skills and human capital (Erjavec et al., 2023). Although SMEs are usually a dynamic force in the economy, the implementation of technology application and innovation presents many difficulties, meaning there are many challenges in improving their efficiency. Given these challenges, we raise the research question: Does the adoption of technology and innovation always positively affect SMEs' firm performance?

In an increasingly competitive environment, business efficiency is always a top concern to SMEs because it determines their existence in the market. Moreover, in the ever-changing environment, SMEs are under tremendous pressure to enhance efficiency, speed, and cost-effectiveness; as a result, they must not only deal with growing challenges, but also strengthen their adaptation capabilities (Taouab & Issor, 2019). Therefore, firm performance is an imperative target of all enterprises. Additionally, Nguyen et al. (2021) affirmed that business operations and supply chain risk resilience are also well-founded in company performance. Hence, the role of technology application and innovation is even more important to SMEs. According to the World Bank (2015) and Gyamera et al. (2023), the integration of information and communication technology (ICT) in organisations has influenced the economic performance of firms in developing countries. Innovation contributes to adding value to products by means of packaging or labelling, adding new features to existing products, or creating new products, for example (Chege et al., 2020). As innovation has been usually linked to the latest knowledge, abilities, or technologies, traditional research has mostly focused on the case of developed countries, not on developing countries (Na & Kang, 2019).

As an emerging logistics market with SMEs constituting approximately 98% of logistics service providers (LSPs), Vietnam was selected for an empirical case study to investigate the effects of technology and innovation on firm performance in a developing country context. The logistics industry has never received such great attention from researchers, business managers, and policymakers as it does today. In Vietnam, although logistics activities have existed for a long time, the concept of logistics was first mentioned in the Commercial Law 2005. The Governmental Decree No. 163/2017/ND-CP, issued on December 30, 2017, concerning the provision of logistics services, categorised 17 logistics services, reflecting the industry's still-immature stage. Our study examines the effects of technology and innovation activities on the firm performance of SMEs in Vietnam's logistics sector. The findings of this study provide practical evidence to help researchers, business managers and policymakers suggest policy implications for enhancing the performance of SMEs, as well as boosting Vietnam's overall logistics capacity. So far, this is one of few studies that specifically focus on SMEs in the logistics sector.

Our study marks an initial move towards bridging the research gap and making a valuable contribution to the literature as well as being useful for decision-makers in that it highlights the impact of technology and innovation on SMEs' performance. Our study demonstrates that technology and innovation do not always have significant effects on firm performance. Among the four technology categories—"internet access", "owning a website", "using software", and "automation"—only the first three significantly enhance both return on assets (ROA) and return on equity (ROE), while "automation" improves only ROA. Of the four innovation categories: "R&D", "product in-

novation", "organisational innovation", and "process innovation" only "organisational innovation" consistently boosts firm performance. This study adds valuable insights to the traditional literature on information systems and IT management practices in logistics, particularly in developing countries like Vietnam.

The rest of this paper is organized as follows: the conceptual model framework and hypotheses development are presented in Section 1. Section 2 covers econometrics models and the testing methodology. Section 3 is dedicated to a case study of Vietnam's logistics sector. The last Section provides conclusions, acknowledges limitations, and suggests research prospects.

1. Model framework and hypotheses development

1.1. Theoretical background

Firstly, the concept of firm performance is generic and has changed over the decades. In theory, firm performance is grounded in two perspectives: the economic perspective, which revolves around maximising profit for the organisation, and the stakeholder approach, which focuses on meeting the needs of individuals or groups who are affected by the organisation's activities (Aifuwa, 2020). The concept of firm performance has become commonly used as a dependent variable in the field of strategic management research (Taouab & Issor, 2019).

The adoption of technology is widely recognized as a key driver of firm performance, particularly for SMEs. The term "technology" used in this study is involved in both ICT and automation. ICT refers to tools and technologies that are used to exchange, distribute and gather information, as well as facilitate communication with each other, either individually or in groups, by using computers and networks that are connected. Furthermore, ICT are media that serve as platforms for the use of both telecommunications and computer technologies in the transmission of information. As highlighted by Lee (2000), ICT facilitates interorganisational linkages, which directly affects the innovation process within an organisational context. Hidalgo and López (2009) also confirmed that innovation can result from new ICT deployment. For automation technology, we need to use a broad definition of automation that encompasses programs that streamline and improve operations through automating even the most basic aspects of tasks, including automatically entering data from manually extracted sources into database fields, as discussed by Tsafnat et al. (2014). Generally, automation in logistics

can be understood as the use of computer software or automated machines to improve the efficiency of logistics companies. The resource-based view (RBV) posits that enterprises can utilise digital technologies to build and implement unique capabilities, such as data analytics, artificial intelligence and digital platforms to achieve their sustainable competitive advantage and improve their overall performance (Wade & Hulland, 2004). For SMEs, internet access, owning a website, using software such as enterprise resource planning (ERP), etc. tools and automation are fundamental digital technologies, which may influence firm performance through organisational capabilities (Wang & Prajogo, 2024), while additionally supporting the optimisation of supply chains by enhancing visibility, communication, and operational efficiency (Wang et al., 2020).

Beyond technology, innovation is widely acknowledged as a core component in enhancing firm performance (Sudrajat et al., 2017). From a RBV perspective, innovation can be regarded as an organisational capability that leverages resources proactively to generate value through new ideas (Wang, 2016). Innovation, according to West and Farr (1990), is the deliberate introduction and use of novel concepts, procedures, products or processes within a role, group or establishment. Such innovation activities are new to the pertinent adoption unit and are intended to offer significant benefits to individuals, communities, groups and organisations. Ramadani et al. (2019) categorised innovation into three primary kinds: (1) "product innovation", which entails launching new or improving existing goods or services; (2) "process innovation", which entails creating new methods of organising and integrating resources into the business production process; and (3) "organisational innovation", which involves the introduction of new or improved operating organisational structure for managing resources of firm. According to the European Commission (2020), research and development (R&D) is a type of innovation activity that involves inventive and methodical efforts to expand the repository of knowledge and develop new applications of existing knowledge. Koellinger (2008) re-affirmed the relationship between technology and innovation, in which innovation follows the adoption of novel technologies.

1.2. Proposed conceptual model framework

The primary purpose of this study is to evaluate how technology and innovation activities affect SMEs' firm performance. Therefore, the target variable is firm performance, whilst technology and innovation are feature variables in addition to control variables. The conceptual model with hypotheses is evolved as follows:

1.2.1. Technology and firm performance

Hidalgo and López (2009) examined factors that lead to and result from ICT adoption in the transportation and logistics service to investigate the performance influence of technology in logistics companies. A sample of data was collected in 2007 from 1,097 businesses involved in logistics-related activities from Germany, France, Poland, Italy, Sweden, Spain, the UK and the US. These businesses are involved in land/road and rail transportation, warehousing and storage, and freight handling, as well as other transportation support activities. Based on actual data from regression models, the authors found empirical evidence corresponding to theoretical predictions, suggesting the positive impact of ICT usage and innovation on company performance. For a particular technology, Ince et al. (2013) assumed that supply chain management practices and ERP systems are crucial for enhancing the performance of companies in Turkey. The authors surveyed 138 managers of Turkish companies and their findings indicated that ERP systems improve firm performance and competitive advantage. Considering transition economies, Gërguri-Rashiti et al. (2017) investigated ICT, innovation, and company performance by using primary data at the firm level. The results demonstrated that by engaging in innovation activities, the performance of the companies is improved. Concerning automation technology, Kromann and Sørensen (2019) confirmed the significant association between automation and profitability and productivity. In addition, Nyaoke and Muturi (2018), improving product quality, employee safety, lead time reduction, labour productivity, and operational performance are the main drivers of logistics automation. Relating to technology, Bellakhal and Mouelhi (2023) surveyed the case of 466 SMEs in Tunisia to shed light on how performance and digitalisation are related. The authors concluded that digitalisation has a positive impact on firm performance, even though the degree of digitalisation among Tunisian SMEs is low due to the lack of necessary resources and skills. In contrast, Guo et al. (2023) used data on Chinese companies during 2013–2020 to examine the impact of digital transformation on total factor productivity and company performance; they discovered the opposite result, due to the increase in management expenses, operation cost rates, and total asset turnover. Hence, to understand better the effect of technology on SMEs' performance, the following set of hypotheses (H_1) is postulated:

H_{1a}: Internet access positively affects firm performance.
H_{1b}: Own website positively affects firm performance.
H_{1c}: Software usage positively affects firm performance.
H_{1d}: Automation positively affects firm performance.

1.2.2. Innovation and firm performance

Most empirical studies corroborate how it is essential for companies to enhance their innovation capabilities for maintaining their competitive advantage. By studying the link between firm performance of international distribution centre operators in Taiwan and their logistics service capabilities, Lu and Yang (2010) found that innovation capability focused on enterprises obtained the greatest performance. Eris and Ozmen (2012) also showed evidence to conclude that innovativeness significantly improves the performance of logistics companies in Turkey. Ul Hassan et al. (2013) investigated how organisational-, product-, process- and marketing innovation all impact on several performance metrics in manufacturing firms in Pakistan. They collected data through survey questionnaires from 150 respondents across the manufacturing, R&D and marketing departments. Their results demonstrated that all innovation categories had positive impacts on firm performance. A typical study focusing on the effect of green innovation was conducted by Chu et al. (2018), who studied 165 third-party logistics providers in China and found a positive effect of green innovation on the financial performance of logistics companies. Another study, by Chege et al. (2020), focused on 240 SMEs in Kenya and the authors used structural equation modelling to analyse the effect of ICT innovation on performance. Their findings indicated that the performance of an enterprise is strongly associated with technical innovation; therefore, it is critical for entrepreneurs to create creative business strategies. Recently, Le et al. (2023) conducted a study on non-state SMEs in Vietnam's manufacturing sector. The results revealed that enterprises implementing innovation activities tend to exhibit better performance than those without, highlighting the crucial role of innovation in improving SMEs' performance. Moreover, in the context of global competitiveness, R&D is essential for enterprises in their business strategies to maintain their competitive position in the sector. Boiko (2022) established that R&D is now increasingly linked to a firm's growth and profitability. Indeed, the positive effect of R&D activity on company performance has been confirmed by many previous researchers (Ramos-Hidalgo et al., 2022). Therefore, to ascertain the effects of innovation activities on SMEs' performance, the following set of hypotheses (H_2) is postulated:

H_{2a}: R&D positively affects firm performance.
H_{2b}: Product innovation positively affects firm performance.
H_{2c}: Organisational innovation positively affects firm performance.
H_{2d}: Process innovation positively affects firm performance.

2.2.3. Firm characteristics and firm performance

To assess the effects of technology and/or innovation on firm performance, researchers have developed research models in different ways. In these models, besides using technology and innovation factors, other factors belonging to characteristics of firms, such as the firm's age, sise, ownership status, manager's education and firm's activities, are used in the models as control variables. The model framework of this study is established by referring to existing studies. According to Admassie and Matambalya (2002), the age of a company has a positive effect on production efficiency; basing on the theory of "learning by doing", authors argued that the older firm tends to produce more efficiently because it has more experience. The authors also agreed that most studies showed the positive effect of a firm's size on its performance. However, Mai et al. (2023) found an inverse relationship between them. Prior to that, when studying the technical efficiency of small-scale industry, Nikaido (2004) also confirmed the negative effect, while Susanti et al. (2022) measured firm size by using the total assets of the firm and found that its size did not affect a firm's performance. As a control variable, ownership is also an important element that affects firm performance, and this was included in the study models by Mai et al., (2023), Ramadani et al. (2019). Regarding human capital, Amran et al. (2014) argued that a more highly educated manager is also a more valuable asset for the firm, since he or she has greater cognitive ability, better decision-making capacity, elevated tolerance for unpredictability, and disposition towards innovation, which together provides them with effective solutions to solve complicated decision-making tasks (Bantel & Jackson, 1989). Additionally, Amran et al. (2014) confirmed that a company performs better when its chief executive officer has a higher education. Furthermore, De Loecker (2013) assumed that firms entering export markets improve their performance by learning through export mechanisms. They explained that businesses operating in global marketplaces can benefit from economies of scale and acquire knowledge by being exposed to more best practices.

In a summary, technology is incorporated in our model framework based on Hidalgo and López (2009), Gërguri-Rashiti et al. (2017), Kromann and Sørensen (2019), Bellakhal and Mouelhi (2023), Guo et al. (2023); meanwhile, innovation is incorporated in the framework based on Alegre et al. (2006), Lu and Yang (2010), Eris and Ozmen (2012), Ul Hassan et al. (2013), and Ramos-Hidalgo et al. (2022). Accordingly, technology encompasses "internet access", "owning a website", "software usage" and "automation", while innovation is measured by "R&D", "product innovation", "organisational innovation" and "process innovation". Factors that are enterprise characteristics constitute as control variables in the model framework. These variables are firm's age, firm's size, ownership status, education of the manager and

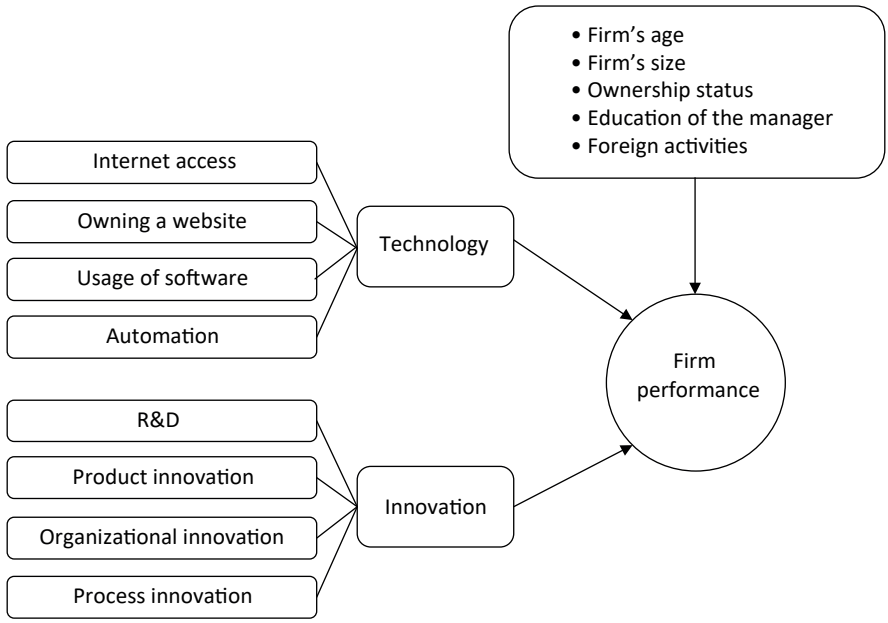

Figure 1. Framework of the study

Source: own elaboration.

foreign activities. Therefore, the generic model framework proposed for this study is presented in Figure 1.

2. Methodology and data

2.1. Econometrics model and methodology

From the framework outlined above, testing models were developed to examine how technology and innovation affect SMEs' firm performance. The two models were created with the same control variables, as follows:

$$FP_i = \alpha_0 + \alpha_1 Firmage_i + \alpha_1 Firmsize_i + \alpha_3 SOEshare_i + \alpha_4 FDIshare_i + \\ + \alpha_5 EM_i + \alpha_6 MX_i + \partial_k Tech_i + \varepsilon_i \quad (1)$$

$$FP_i = \alpha_0 + \alpha_1 Firmage_i + \alpha_1 Firmsize_i + \alpha_3 SOEshare_i + \alpha_4 FDIshare_i + \\ + \alpha_5 EM_i + \alpha_6 MX_i + \tau_k In_i + \vartheta_i \quad (2)$$

In general, the equation 1 and 2 can be rewritten in a short form as the following:

$$FP_i = \alpha_0 + \sum_{i=1}^{k} \beta_i x_i + u_i \quad (3)$$

All variables x_i are clarified in Table A1 in the Appendix, FP_i denotes financial performance (ROA or ROE), while ε_i, ϑ_i and u_i are white noises.

To estimate these models, ordinary least-squares (OLS) is initially used. A key presumption in the OLS method is homoskedasticity, which means that residuals for a regression model do have a constant variance: $Var(u_i) = E(u_i^2) = \sigma^2 \; \forall i = 1, n$. In the event that the homoskedasticity presumption is not met, it leads to biased and inconsistent estimators of the covariance matrix of the parameter estimations, which can result in a variable being found to be significant when in reality it is not (Hayes & Cai, 2007). Thus, White's test for the null hypothesis H_0: homoskedasticity is employed. If there is strong evidence to reject H_0, it indicates that there is a presence of the diagnosis of heteroskedasticity in the model, which means $E(u_i^2) = \sigma_i^2$. In such cases, the OLS estimator no longer meets the criteria for being the best linear unbiased estimator (BLUE) and may not be an effective tool (Romano & Wolf, 2017). To address heteroscedasticity, the robust standard errors technique (hereafter: Robust) can be applied for model regression to adjust the standard errors of the coefficients. Specifically, HC1—one of the heteroscedasticity-consistent (HC) estimators—is used, as recommended by Long and Ervin (2000) for its effectiveness. While Robust can provide more reliable standard errors, this method has limitations, such as not changing the estimated coefficients, which make it still less efficient than those obtained from methods specifically designed to handle heteroskedasticity, such as weighted least squares (WLS).

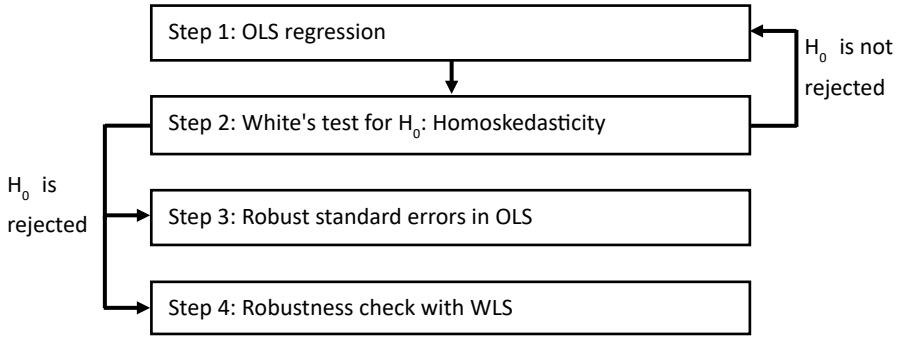

Figure 2. Flowchart for model estimation

Source: own elaboration.

WLS is more efficient than using Robust in OLS because it directly accounts for heteroskedasticity by weighting observations based on their variance. Under heteroskedasticity, WLS approach yields effective and consistent results in comparison to the OLS method (Safa, 2005) and can provide significant improvement over the OLS estimator (Harris et al., 2020). Therefore, the entire process for estimating models in this study is designed as shown in Figure 2. If the general model (model 3) suffers from heteroscedasticity, the WLS method is applied as a robustness check to ensure that the resulting estimators are BLUE. Obviously, assuming that σ_i^2 were determined, to fix heteroskedasticity in the model 3 we divide both sides of the equation 3 with σ_i^2, then the model regression can be written as:

$$\frac{FP_i}{\sigma_i} = \alpha_0 \left(\frac{1}{\sigma_i}\right) + \sum_{i=1}^{k} \beta_i \left(\frac{x_i}{\sigma_i}\right) + \frac{u_i}{\sigma_i} \tag{4}$$

With this new model:

$$Var(u_i^*) = Var\left(\frac{u_i}{\sigma_i}\right) = E\left(\frac{u_i}{\sigma_i}\right)^2 = \frac{1}{\sigma_i^2} E(u_i^2) = 1 \tag{5}$$

since $E(u_i^2) = \sigma_i^2$.

2.2. Measurement

All variables with measurement, expected sign and reference sources used in this study were displayed in Table A1 in the Appendix. Numerous metrics have been proposed to assess firm performance, such as ROA (Ali et al., 2022), ROE (Zhang et al., 2018), Tobin-Q (Akhtar, 2022), etc. A literature review on corporate performance measurements conducted by Al-Matari et al. (2014) showed that ROA is a unique metric, which is most frequently employed—with 46% use, followed by 27% for ROE, and profit margin with 8%. Hagel et al. (2010) pointed out that ROA is a better measure for assessing the financial performance of companies than income statement profitability measures such as return on sales, and it can provide a more thorough viewpoint on the fundamentals of the business, including efficient use of assets. Our study concentrates on the profitability metrics of financial performance indicators, thus both ROA and ROE are preferred to use as proxies for SMEs' firm performance.

3. The case of Vietnam's logistics sector

3.1. Data collection

Following Koellinger (2008) and Na and Kang (2019), this study employs cross-sectional data for analysing the effects of technology and innovation adoption on SMEs' firm performance. Vietnam, an emerging logistics market, was chosen as an ideal case study for a developing country. The dataset encompasses SMEs in the logistics sector of the country from an enterprise survey conducted by the General Statistics Office of Vietnam (GSO) in 2021, taking in 63 provinces and cities. This study emphasises financially healthy, profitable SMEs in the expectation of providing more actionable insights for enterprises that are already performing well. Unlike most of studies, which usually classify the size of enterprises solely based on quantities of labour or capital, the criteria applied for identifying SMEs in this study were based on Article 5 of the Decree No. 80/2021/ND-CP, issued on August 26, 2021 by Vietnam's government, concerning "Elaboration of some articles of the law on provision of assistance for SMEs". Accordingly, SMEs in the field of logistics are enterprises that have an average annual number of employees of no more than 100 employees and total capital recorded in the same year not exceeding 100 billion VND.

3.2. Data processing

The raw dataset required extensive cleaning, including removing duplicates and handling outliers to ensure accuracy and reliability, and also creating new variables for regression modelling. The final dataset includes 11,630 SMEs in Vietnam's logistics sector. Since cross-sectional data usually suffers from heteroskedasticity, following Masood et al. (2009) and Skvarciany et al. (2019), ROA and ROE were log-transformed in order to reduce heteroskedasticity and make highly skewed variables more symmetric and follow normal distribution more closely. Then, the process for model estimation as shown in the flowchart of Figure 2 is performed. The significance level is set to 0.05 ($\alpha = 5\%$) for all the statistical tests, meaning there is a 95% confidence level at least. All stages of data analysis are supported by the software tool STATA version 17.

3.3. Descriptive statistics

The collected data includes a total of 11,630 operating SMEs in Vietnam's logistics sector in 2021. The dataset encompasses a wide range of logistics

services, ranging from very small to medium-sized enterprises, and from newly established businesses to those with a long-standing operational history of up to 29 years (Table 1). The dataset comprises state-owned enterprises (SEOs), which constitute 0.55%, and foreign direct investment (FDI) enterprises, making up 2.24%. On average, the government holds 55.26% ownership in 64 SOEs, whereas 260 FDI enterprises have an average foreign ownership of 82%. The high level of foreign ownership in FDI enterprises reflects Vietnam's strategic openness to multinational corporations and underscores the country's successful attraction of FDI in the logistics sector. Figure 3 illustrates that a significant proportion of enterprises fall under the categories of logistics, with 49.14% engaged in "Freight transport by other motor vehicles (except special-purpose motor vehicles)", followed by "Freight transport by specialised vehicles" at 13.36% and "Other transportation support activities not elsewhere classified (activities of air cargo agents; activities of customs agents" at 11.07%. Additionally, "Inland freight water transport by motor vehicles" accounts for 3.72%; "Shipping agency/freight forwarding services" for 3.45% and "Logistics, including: planning, designing and supporting operations of transportation, warehousing and distribution" for 3.44% (for more information on the categories of logistics services, see Table A2 in the Appendix).

Table 1 shows the standard deviation of ROE (14.1518) is larger than that of ROA (7.7274), indicating that ROA is relatively more stable than ROE. The

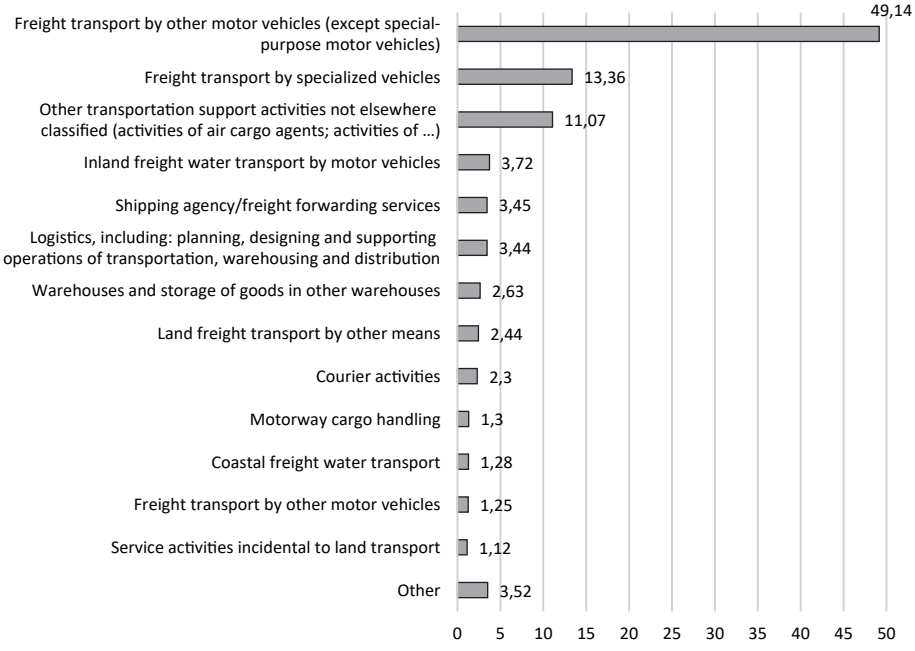

Figure 3. Percentage of LSPs by categories of logistics services

Source: own elaboration.

table also shows that 54.02% of managers have a university degree or higher. Among these SMEs, 7.73% of enterprises engage in import and export activities. Regarding technology adoption, a significant majority of enterprises, specifically 75.07%, utilise Internet connections for their business operations. In contrast, 39.65% of enterprises use management software or platforms. However, owning a website is relatively low at 7.23%, and only 1.23% of enterprises use automation technology systems. With respect to innovation initiatives, a minimal percentage of enterprises, only 0.86%, engage in R&D. Product innovation is implemented by 4.46% of enterprises, while innovation in the organisational model is adopted by 7.96%. Additionally, 6.34% of enterprises innovate in their production and business processes.

Table 1. Descriptive statistics of all raw variables used in models

Variable	Unit	Observations	Mean	Standard deviation	Min	Max
ROA	%	11,630	3.6375	7.7274	4.68E-05	95.96
ROE	%	11,630	7.5898	14.1518	0.0001	99.9378
Firm's age	number of years	11,630	7.5474	5.1040	1	29
Firm's size	million dong	11,630	20,972.89	82,035.18	6.8	3,013,255
SOEshare	%	11,630	0.3041	4.5766	0	100
FDIshare	%	11,630	1.8333	12.5966	0	100
EM	dummy	11,630	0.5402	0.4984	0	1
MX	dummy	11,630	0.0773	0.2671	0	1
Tech_Net	dummy	11,630	0.7507	0.4326	0	1
Tech_Web	dummy	8,731	0.0723	0.2590	0	1
Tech_Us	dummy	11,630	0.3965	0.4892	0	1
Tech_Auto	dummy	11,630	0.0123	0.1102	0	1
In_RD	dummy	11,630	0.0086	0.0923	0	1
In_Product	dummy	11,630	0.0446	0.2065	0	1
In_Organiz	dummy	11,630	0.0796	0.2707	0	1
In_Process	dummy	11,630	0.0634	0.2436	0	1

Note: Definitions of variables are presented in Table A1 in the Appendix.

Source: own elaboration.

The distribution of logistics SMEs across 63 provinces / cities of Vietnam reveals a notable concentration in key economic centres. Ho Chi Minh City, the primary economic and commercial centre, hosts the largest share at 31.56% of enterprises; Hanoi, the capital, follows with 10.03%; Hai Phong, a crucial port city, has 8.02%; Binh Duong and Dong Nai adjacent to Ho Chi Minh City, account for 5.17% and 5.05%, respectively; Da Nang and Binh Dinh in the central coastal area, have 2.83% and 2.55%, respectively, while Ba Ria-Vung Tau has 2.15%. All other provinces and cities have less than 2% of total enterprises.

3.4. Results and discussion

As the first step, OLS regression was performed for both models 1 & 2, utilising two metrics of firm performance: ROA and ROE. Then, White's test for the null hypothesis H_0: Homoskedasticity was implemented. The results indicate that all OLS regression models are statistically significant at the 0.01 level, with Prob > *F* values of 0.0000. However, these models show signs of heteroskedasticity, as evidenced by White's test, which reveals a Prob > chi^2 value of 0.0000. So, the null hypothesis H_0: Homoskedasticity was rejected at the 0.01 level. Since heteroskedasticity is present, the standard errors of the OLS estimates are not reliable. As a common method, the Robust technique can be applied to produce more accurate standard errors. Tables 2 & 3 present the regression results conducted by Robust in OLS on the effects of technology and innovation on firm performance. Basically, Robust is designed to adjust for heteroskedasticity without changing the OLS regression coefficients. As the last step shown in Figure 2, we performed a robustness check to examine the effects of technology and innovation on firm performance using WLS. The full WLS analysis results are presented in Tables 4 & 5.

3.4.1. The effect of technology on firm performance

The results from regressing the effects of technology categories on firm performance using Robust in OLS, as shown in Table 2, indicate that all models are statistically significant at the 0.01 level, with Prob > *F* values of 0.0000. Specifically, "Internet access", "owning a website" and "using software" significantly affect both ROA and ROE at the 0.01 level, indicating a strong positive relationship between these technology categories and firm performance. This suggests that enterprises adopting these technologies register better performance compared to those that do not. These findings are supported by previous studies such as Ince et al. (2013), Gërguri-Rashiti et al. (2017), Bellakhal and Mouelhi (2023), and Guo et al. (2023). In contrast, we did not

find any evidence to support the significant effect of automation on SMEs' performance at the 0.05 level. Thus, "automation" does not significantly affect ROA or ROE at this threshold, suggesting that it does not contribute to firm performance within the context of this study. Our finding differs from the results of Kromann and Sørensen (2019), who reported a significant association between "automation" and profitability and productivity. The *p*-values for "automation" in relation to ROA and ROE when using Robust in OLS regression are above the 0.05 level, recorded at 0.058 and 0.666, respectively. These findings are in line with the proposed hypotheses: H_{1a}, H_{1b} and H_{1c}, while it is not consistent with the hypothesis H_{1d}, which reports a positive effect of "automation" with firm performance. This difference suggests that the effect of "automation" may vary across different contexts or may require specific conditions to manifest.

Additionally, the study found that firm's age positively affects firm performance in all models at the 0.05 level, suggesting that older enterprises tend to perform better. This conclusion is supported by Admassie & Matambalya (2002) through the theory of "learning by doing". In contrast, our study found the significant negative effect of firm's size measured by the total assets of enterprises. This finding is different to most studies, which usually support the positive relationship between the size and the performance of firms. However, this negative effect aligns with the conclusion of Nikaido (2004), who found that firm's size had a significant negative effect on technical efficiency. The study suggests that SMEs receiving supportive policies might have prevented potential capacity. Mai et al. (2023) also noted that many studies have identified the adverse relationship between the size of enterprises and their performance.

Furthermore, this paper verifies the significant positive effect of both foreign ownership and state ownership on firm performance. However, our findings on state ownership differ from Mai et al. (2023), who found a negative impact in the Vietnamese shipping sector, reflecting ongoing debate about the influence of government ownership (Sun et al., 2002). The positive effect of foreign ownership on firm performance can be attributed to technological, managerial, innovation and skills transfers through FDI inflows (Nyeadi, 2023). Notably, our study found that state ownership has a stronger effect on ROA, while foreign ownership has a greater effect on ROE. Specifically, the coefficients for "SOEshare" are consistently higher than "FDIshare" for ROA, whereas for ROE, "FDIshare" coefficients exceed those of "SOEshare". This may be explained that SOEs enhance ROA by promoting stable and efficient asset utilisation, while FDI enterprises boost ROE through profit-maximising strategies and better access to resources and expertise.

Our study also demonstrates that the education of the manager is a critical factor affecting SMEs' firm performance, which is consistent with the findings of Amran et al. (2014). Mai et al. (2023) highlight that a manager's capacity

Table 2. Effects of technology categories on firm performance: Robust in OLS

	ROA				ROE			
Model	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**
LFirmage	0.0867*** (0.0222)	0.0513** (0.0256)	0.0808*** (0.0222)	0.0886*** (0.0222)	0.2015*** (0.0231)	0.1543*** (0.0268)	0.1965*** (0.0231)	0.2035*** (0.0231)
LFirmsize	–0.3467*** (0.0137)	–0.3255*** (0.0155)	–0.3561*** (0.0137)	–0.3450*** (0.0136)	–0.1519*** (0.0138)	–0.1332*** (0.0156)	–0.1601*** (0.0139)	–0.1492*** (0.0137)
SOEshare	0.0303*** (0.0029)	0.0253*** (0.0030)	0.0297*** (0.0029)	0.0304*** (0.0029)	0.0184*** (0.0027)	0.0148*** (0.0027)	0.0179*** (0.0026)	0.0185*** (0.0026)
FDIshare	0.0230*** (0.0016)	0.0210*** (0.0016)	0.0227*** (0.0016)	0.0231*** (0.0016)	0.0217*** (0.0015)	0.0201*** (0.0016)	0.0214*** (0.0015)	0.0217*** (0.0015)
EM	0.2878*** (0.0325)	0.3197*** (0.0378)	0.2848*** (0.0325)	0.2914*** (0.0325)	0.2695*** (0.0340)	0.2910*** (0.0395)	0.2672*** (0.0340)	0.2734*** (0.0340)
MX	0.7216*** (0.0636)	0.6167*** (0.0680)	0.6892*** (0.0635)	0.7374*** (0.0632)	0.7147*** (0.0637)	0.6383*** (0.0675)	0.6876*** (0.0637)	0.7331*** (0.0634)
Tech_Net	0.1171*** (0.0374)				0.1208*** (0.0392)			
Tech_Web		0.5019*** (0.0773)				0.3280*** (0.0760)		

	ROA				ROE			
Model	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**
Tech_US			0.2044*** (0.0336)				0.1853*** (0.0350)	
Tech_Auto				0.2601 (0.1375)				0.0614 (0.1421)
_cons	2.4662*** (0.1154)	2.4208*** (0.1316)	2.5712*** (0.1144)	2.5293*** (0.1148)	1.3455*** (0.1156)	1.3601*** (0.1326)	1.4477*** (0.1152)	1.4042*** (0.1153)
Observations	11,630	8,731	11,630	11,630	11,630	8,731	11,630	11,630
F test	*F*(7, 11622) = 147.35	*F*(7, 8723) = 121.58	*F*(7, 11622) = 153.88	*F*(7, 11622) = 147.44	*F*(7, 11622) = 103.81	*F*(7, 8723) = 87.55	*F*(7, 11622) = 107.29	*F*(7, 11622) = 103.34
Prob > *F*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.1026	0.1061	0.1046	0.1021	0.0608	0.0647	0.0622	0.0600

Note: Robust standard errors are enclosed in parentheses; ** *p*-value < 0.05; *** *p*-value < 0.01.

Source: own elaboration.

to manage and utilize capital is crucial for firm performance. In addition, our results align with De Loecker's (2013), indicating that SMEs engaged in import and export activities tend to exhibit higher firm performance. This confirms Singh et al. (2022), who argue that the process of internationalisation eventually helps to enhance SMEs' economic performance.

3.4.2. The effect of innovation on firm performance

The results from regressing the effects of innovation categories on firm performance using Robust in OLS, as shown in Table 3, indicate that all models are statistically significant at the 0.01 level, with Prob > *F* values of 0.0000. We found that "organisational innovation" consistently demonstrates a positive and significant effect on firm performance measured by both ROA and ROE at the 0.05 level across all models. This implies that if enterprises conduct "organisational innovation" or introduce a new or improved operating organisational structure for managing resources of firm, they tend to have higher performance than those without. In contrast, our analysis did not find any significant effects of "R&D", "product innovation", or "process innovation" on ROA or ROE at the 0.05 level. The regression analysis of the effect of innovation on ROA using Robust in OLS indicates high p-values for "R&D" (0.115), "product innovation" (0.356), and "process innovation" (0.401), suggesting no significant impact. Similarly, the regression of innovation's effect on ROE using Robust in OLS also shows high *p*-values for "R&D" (0.232), "product innovation" (0.327), and "process innovation" (0.396). Therefore, the results of our study suggest that "organisational innovation" is more effective in enhancing firm performance than other types of innovation. This finding is consistent with our hypothesis H_{2c}, which indicates that "organisational innovation" positively affects firm performance, although it is not consistent with the hypotheses H_{2a}, H_{2b} and H_{2d}. Concerning the effect of innovation, Table 3 indicates the limited effect of innovation on SMEs' performance in Vietnam's logistics sector. Tuan et al. (2016) studied the effects of different innovation categories on the performance of enterprises in the supporting industries in Hanoi, Vietnam. They concluded that organisational and process innovation had a positive effect on firm performance, but product innovation did not show a significant effect. On the contrary, Ramadani et al. (2019) studied transition economies and found the positive impact of product innovation on firm performance. Similarly, Na & Kang (2019) focused on enterprises in the manufacturing sector in Vietnam, Indonesia and Malaysia. These authors found that introducing new business production processes or significantly improving existing ones has a negative effect on firm performance. With R&D, Boiko (2022) used data from journals from 1980–2020 and showed the contradictory relationship between R&D and performance. We can therefore

Table 3. Effects of innovation categories on firm performance: Robust in OLS

	ROA				ROE			
Model	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**
LFirmage	0.0890*** (0.0222)	0.0886*** (0.0222)	0.0884*** (0.0222)	0.0885*** (0.0222)	0.2037*** (0.0231)	0.2034*** (0.0231)	0.2034*** (0.0231)	0.2034*** (0.0231)
LFirmsize	–0.3446*** (0.0136)	–0.3443*** (0.0136)	–0.3466*** (0.0136)	–0.3447*** (0.0136)	–0.1496*** (0.0137)	–0.1495*** (0.0137)	-0.1511*** (0.0138)	-0.1499*** (0.0138)
SOEshare	0.0304*** (0.0029)	0.0304*** (0.0029)	0.0304*** (0.0029)	0.0304*** (0.0029)	0.0185*** (0.0027)	0.0185*** (0.0026)	0.0185*** (0.0026)	0.0185*** (0.0026)
FDIshare	0.0231*** (0.0016)	0.0231*** (0.0016)	0.0231*** (0.0016)	0.0231*** (06.001)	0.0218*** (0.0015)	0.0217*** (0.0015)	0.0217*** (0.0015)	0.0217*** (0.0015)
EM	0.2901*** (0.0325)	0.2908*** (0.0325)	0.2898*** (0.0325)	0.2909*** (0.0325)	0.2723*** (0.0340)	0.2725*** (0.0340)	0.2721*** (0.0340)	0.2727*** (0.0340)
MX	0.7329*** (0.0634)	0.7364*** (0.0634)	0.7214*** (0.0637)	0.7356*** (0.0637)	0.7283*** (0.0636)	0.7296*** (0.0636)	0.7194*** (0.0639)	0.7292*** (0.0638)
In_RD	0.2670 (0.1694)				0.2026 (0.1693)			
In_Product		0.0708 (0.0767)				0.0785 (0.0801)		

	ROA				ROE			
Model	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**
In_Organiz			0.1563*** (0.0582)				0.1199** (0.0606)	
In_Process				0.0563 (0.0671)				0.0580 (0.068)
_cons	2.5274*** (0.1149)	2.523611 *** (0.1147)	2.5362*** (0.1146)	2.5268*** (0.1147)	1.4070*** (0.1153)	1.4050*** (0.1151)	1.4138*** (0.1152)	1.4081*** (0.1154)
Observations	11,630	11,630	11,630	11,630	11,630	11,630	11,630	11,630
F test	*F*(7, 11622) = 147.21	*F*(7, 11622) = 147.14	*F*(7, 11622) = 148.67	*F*(7, 11622) = 147.50	*F*(7, 11622) = 103.39	*F*(7, 11622) = 103.41	*F*(7, 11622) = 104.03	*F*(7, 11622) = 103.46
Prob > *F*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.1020	0.1019	0.1024	0.1019	0.0601	0.0601	0.0603	0.0600

Note: Robust standard errors are enclosed in parentheses; ** *p*-value < 0.05; *** *p*-value < 0.01.

Source: own elaboration.

see that there are some clear conflicts regarding the effect of innovation on firm performance.

In line with earlier findings, the Robust analysis confirms that all the control variables significantly affect firm performance at the 0.01 level. Specifically, firm's age positively affects firm performance across all models, suggesting that older firms perform better. It also reaffirms the negative effect of firm's size on firm performance. Both state ownership and foreign ownership continue to exhibit positive effects on firm performance. Furthermore, state ownership has a stronger effect on ROA, while foreign ownership has a greater effect on ROE. Additionally, the Robust results confirm that the education of the manager significantly affects SME performance and that international trade activities such as import and/or export contribute positively to firm performance, aligning with the conclusions before.

3.5. Robustness check

3.5.1. The effect of technology on firm performance

Table 4 presents the effects of technology categories on firm performance using WLS regression. The results strongly confirm the consistent effects of "internet access", "owning a website" and "using software" on firm performance at the 0.01 level. This finding aligns with the hypotheses proposed H_{1a}, H_{1b} and H_{1c}. In particular, the coefficient for "internet access" is 0.1078, indicating that, on average, a logistics enterprise with "internet access" tends to have a 10.78% higher ROA than those without "internet access" (*ceteris paribus*). Similarly, the differences in ROA of enterprises with "owning a website" and "using software" compared to enterprises without using them are 48.15% and 19.99%, respectively (*ceteris paribus*). Additionally, the results indicate that "internet access", "owning a website" and "using software" are associated with increases in ROE of 11.05%, 31.90%, and 18.31%, respectively (*ceteris paribus*). These findings are consistent with Bellakhal & Mouelhi (2023), who used a firm-level dataset of 466 SMEs and found that digitalisation is positively in line with firms' performance. Similarly, Wilson et al. (2015) indicated that the use of IT and information integration systems contributed to the firm performance of logistics companies.

Unlike robust regressions (Table 2), the WLS regression in Table 4 shows a positive significant effect of "automation" on ROA at the 0.05 level, but no significant effect on ROE, with a p-value of 0.595. Therefore, this finding provides partial support for our hypothesis H_{1d} that automation positively affects firm performance. This difference may be attributed to the essence of ROA and ROE. "Automation" can enhance the efficiency of operations by stream-

Table 4. Effects of technology categories on firm performance: WLS regression

	ROA				ROE			
Model	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**
LFirmage	0.0849*** (0.0210)	0.0511** (0.0243)	0.0787*** (0.0210)	0.0867*** (0.0201)	0.1915*** (0.0220)	0.1484*** (0.0254)	0.1848*** (0.0220)	0.1938*** (0.0220)
LFirmsize	–0.3433*** (0.0121)	–0.3221*** (0.0139)	–0.3523*** (0.0122)	–0.3422*** (0.0121)	–0.1424*** (0.0125)	–0.1257*** (0.0144)	–0.1496*** (0.0127)	–0.1403*** (0.0125)
SOEshare	0.0284*** (0.0030)	0.0244*** (0.0033)	0.0278*** (0.0030)	0.0285*** (0.0030)	0.0169*** (0.0031)	0.0139*** (0.0033)	0.0163*** (0.0030)	0.0171*** (0.0030)
FDIshare	0.0215*** (0.0011)	0.0202*** (0.0013)	0.0212*** (0.0011)	0.0216*** (0.0011)	0.0202*** (0.0011)	0.0192*** (0.0012)	0.0199*** (0.0010)	0.0203*** (0.0010)
EM	0.2744*** (0.0328)	0.3103*** (0.0381)	0.2719*** (0.0328)	0.2773*** (0.0328)	0.2693*** (0.0342)	0.2906*** (0.0397)	0.2677*** (0.0342)	0.2727*** (0.0342)
MX	0.7134*** (0.0600)	0.61997*** (0.0653)	0.6804*** (0.0602)	0.7276*** (0.0596)	0.6981*** (0.0599)	0.6331*** (0.0655)	0.6668*** (0.0598)	0.7144*** (0.0595)
Tech_Net	0.1078*** (0.0375)				0.1105*** (0.0393)			
Tech_Web		0.4815*** (0.0734)				0.3190*** (0.0742)		

	ROA				ROE			
Model	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**	**Tech_Net**	**Tech_Web**	**Tech_US**	**Tech_Auto**
Tech_US			0.1999*** (0.0339)				0.1831*** (0.0352)	
Tech_Auto				0.2902** (0.1428)				0.0781 (0.1471)
_cons	2.4581*** (0.1041)	2.3995*** (0.1196)	2.5546*** (0.1027)	2.5197*** (0.1026)	1.2922*** (0.1083)	1.3090*** (0.1239)	1.3822*** (0.1067)	1.3485*** (0.1067)
Observations	11,630	8,731	11,630	11,630	11,630	8,731	11,630	11,630
F test	*F*(7, 11622) = 203.25	*F*(7, 8723) = 153.54	*F*(7, 11622) = 207.86	*F*(7, 11622) = 203.24	*F*(7, 11622) = 140.25	*F*(7, 8723) = 106.13	*F*(7, 11622) = 146.30	*F*(7, 11622) = 140.01
Prob > *F*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.1091	0.1097	0.1113	0.1091	0.0779	0.0785	0.0810	0.0778

Note: Robust standard errors are enclosed in parentheses; ** *p*-value < 0.05; *** *p*-value < 0.01.

Source: own elaboration.

lining processes, reducing errors, and then increasing productivity, which can directly improve the utilisation of assets, leading to better ROA. In contrast, ROE simply measures profitability relative to shareholders' equity, and "automation" might not have an immediate effect on ROE. Despite the important role of automation technology regarding firm profitability and productivity, as highlighted by Kromann and Sørensen (2019), our empirical analysis reveals that only 1.23% of SMEs in the data sample use automation technology systems in their logistics activities (Table 1).

One more time, the WLS results in Table 4 confirms all the control variables significantly affect firm performance at the 0.05 level. Moreover, the study reveals that state ownership has consistently larger effects on ROA compared to foreign ownership, whereas foreign ownership has a greater effect on ROE than state ownership.

3.5.2. The effect of innovation on firm performance

Table 5 presents the effects of innovation categories on firm performance using WLS regression. The regression results show a consistent significant effect of "organisational innovation" on firm performance at the 0.05 level, similar to the findings from Robust regressions. This supports our hypothesis H_{2c}. The coefficients for the variable "In_Organiz" are 0.1558 for ROA and 0.1179 for ROE, indicating that logistics enterprises with "organisational innovation" tend to have a 15.58% higher ROA and an 11.79% higher ROE than those without (*ceteris paribus*). However, we did not find a significant effect of other categories of innovation—"R&D", "product innovation", or "process innovation"—at the 0.05 level, which does not support the hypotheses H_{2a}, H_{2b}, H_{2d}. This is consistent with Koellinger (2008), who found that engaging in innovative activities does not always result in higher profitability. As was the case with Robust regressions, all control variables were proved to consistently affect SMEs' firm performance at the 0.01 level.

Conclusions

The goal of this study was to investigate how the adoption of technology and innovation affects SMEs' firm performance. Focusing on 11,630 financially stable and profitable SMEs in Vietnam's logistics sector, we aimed to provide robust, interpretable, and actionable insights for firms already performing well. This research is among the few studies targeting SMEs in the logistics sector. We developed a model framework where "technology" was

Table 5. Effects of innovation categories on firm performance: WLS regression

	ROA				ROE			
Model	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**
LFirmage	0.0872*** (0.0210)	0.08678*** (0.0210)	0.0865*** (0.0210)	0.0867*** (0.0210)	0.1942*** (0.0220)	0.1938*** (0.0220)	0.1937*** (0.0220)	0.1937*** (0.0220)
LFirmsize	–0.3418*** (0.0121)	–0.3413*** (0.0121)	–0.3436*** (0.0121)	–0.3415*** (0.0121)	–0.1407*** (0.0125)	–0.1406*** (0.0125)	–0.1424*** (0.0126)	–0.1408*** (0.0126)
SOEshare	0.0285*** (0.0030)	0.0285*** (0.0030)	0.0285*** (0.0030)	0.0285*** (0.0030)	0.0170*** (0.0030)	0.0171*** (0.0030)	0.0171*** (0.0030)	0.0170*** (0.0030)
FDIshare	0.0217*** (0.0011)	0.0216*** (0.0011)	0.0216*** (0.0011)	0.0216*** (0.0011)	0.0203*** (0.0010)	0.0203*** (0.0011)	0.0203*** (0.0011)	0.0203*** (0.0011)
EM	0.2760*** (0.0328)	0.2767*** (0.0328)	0.2755*** (0.0328)	0.2769*** (0.0328)	0.2714*** (0.0342)	0.2718*** (0.0342)	0.2713*** (0.0342)	0.2720*** (0.0342)
MX	0.7234*** (0.0598)	0.7271*** (0.0598)	0.7121*** (0.0600)	0.7268*** (0.0599)	0.7106*** (0.0597)	0.7116*** (0.0597)	0.7018*** (0.0600)	0.7113*** (0.0597)
In_RD	0.2692 (0.1695)				0.1939 (0.1716)			
In_Product		0.0651 (0.0770)				0.0734 (0.0788)		

	ROA				ROE			
Model	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**	**In_RD**	**In_Process**	**In_Organiz**	**In_Process**
In_Organiz			0.1558*** (0.0590)				0.1179** (0.0604)	
In_Process				0.0464 (0.0659)				0.0519 (0.0674)
_cons	2.517*** (0.1026)	2.5129*** (0.1026)	2.5257*** (0.1026)	2.5149*** (0.1028)	1.3512*** (0.1067)	1.3493*** (0.1067)	1.3606*** (0.1068)	1.3512 *** (0.1068)
Observations	11,630	11,630	11,630	11,630	11,630	11,630	11,630	11,630
F test	*F*(7, 11622) = 202.65	*F*(7, 11622) = 202.41	*F*(7, 11622) = 203.63	*F*(7, 11622) = 202.37	*F*(7, 11622) = 139.98	*F*(7, 11622) = 139.79	*F*(7, 11622) = 140.13	*F*(7, 11622) = 139.91
Prob > *F*	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.1088	0.1087	0.1092	0.1086	0.0778	0.0777	0.0778	0.0777

Note: Robust standard errors are enclosed in parentheses; ** *p*-value < 0.05; *** *p*-value < 0.01.

Source: own elaboration.

measured by "internet access", "owning a website", "using software" and "automation", whilst innovation activities included "R&D", "product innovation", "organisational innovation" and "process innovation". The control variables in the models included firm's age, firm's size, status of ownership, education of the manager and foreign activities.

Initially, OLS regression was performed, followed by White's test, which showed the existence of heteroskedasticity in all models. The Robust technique was then applied to produce more accurate standard errors in OLS regressions. Finally, we performed a robustness check to examine the effects of technology and innovation on firm performance using weighted least squares. The empirical results highlighted the insight that the effects of technology on firm performance may differ according to different metrics of firm performance. In particular, we found robust relationships of "Internet access", "owning a website" and "using software" on firm performance at the 0.01 level across Robust and WLS regressions, while "automation" only affects ROA significantly. The finding also revealed a consistent, positive and significant effect of "organisational innovation" on firm performance at the 0.05 level in all regression models, indicating that not all forms of innovation significantly affect SMEs' firm performance. Additionally, the study confirmed the positive significant of firm's age, state ownership, education of the manager, and foreign activities on firm performance, and also the negative significant effect of firm's size measured by total assets. Notably, state ownership appeared to have a stronger effect on ROA, while foreign ownership had a greater effect on ROE, indicating a potential effect of different capital structures on SMEs' profitability.

Understanding the extent to which technology adoption and innovation is essential for SMEs, as well as their effects on firm performance, offers valuable insights for practitioners and policymakers. Despite the challenges associated with building data on the level of technology and innovation application for SMEs, addressing this gap presents an important avenue for future research. Moreover, future studies may consider additional financial performance metrics, such as return on sales, to fully understand the effects.

Appendix

Table A1. List of all variables used in the study

Variables	Explanation	Expected sign	Study
FP – Financial performance measures			
1 ROA	Return on assets = Net income/Total assets		Salim & Susilowati (2020), Ali et al. (2022)
2 ROE	Return on equity = Net income/Total equity		Zhang et al. (2018), Guo et al. (2023)
Control variables			
1 Firmage	Duration since the company established till 2021 (in the natural logarithm)	+	Ramadani et al. (2019), Jang & Ahn (2021)
2 Firmsize	Natural logarithm of total assets	+/–	Huang et al. (2022), Mai et al. (2023)
3 SOEshare	Ownership, as percentage of state ownership of the enterprise	+/–	Sun et al. (2002), Mai et al. (2023)
4 FDIshare	Ownership, as percentage foreign ownership of the enterprise	+	Ramadani et al. (2019), Nyeadi (2023)
5 EM	= 1 if the manager's education is from university and above; = 0 otherwise	+	Amran et al. (2014), Ali et al. (2022)
6 MX	= 1 if the enterprise is covering import and (or) export activities; = 0 otherwise	+	De Loecker (2013), Mai et al. (2023)
Feature variables regarding technology			
1 Tech_Net	= 1 if the enterprise uses internet access in production and business activities; = 0 otherwise	+	Gërguri-Rashiti et al. (2017), Zhong et al. (2020)
2 Tech_Web	= 1 if the enterprise has its own website; = 0 otherwise	+	Gërguri-Rashiti et al. (2017)
3 Tech_US	= 1 if the enterprise uses software in production and business activities; = 0 otherwise	+	Hidalgo & López (2009), Gërguri-Rashiti et al. (2017)
4 Tech_Auto	= 1 if the enterprise uses automation technology in production and business activities; = 0 otherwise	+	Nyaoke & Muturi (2018), Kromann & Sørensen (2019)
Feature variables regarding innovation			
1 In_RD	= 1 if the enterprise has R&D activity; = 0 otherwise	+	Ramos-Hidalgo et al. (2022), Boiko (2022)

Variables	Explanation	Expected sign	Study
2 In_Product	= 1 if the enterprise has product innovation; = 0 otherwise	+	Ramadani et al. (2019), Le et al. (2023)
3 In_Organiz	= 1 if the enterprise has innovation/ improvement to the operating organization model; = 0 otherwise	+	Ul Hassan et al. (2013), Tuan et al. (2016)
4 In_ Process	= 1 if the enterprise has innovation/ improvement to production and business processes; = 0 otherwise	+	Ul Hassan et al (2013), Ramadani et al. (2019)

Source: own elaboration.

Table A2. List of all categories of logistics activities in the data sample

Scode 5	Categories of logistics activities	Frequency	Percent
49332	Freight transport by other motor vehicles (except special-purpose motor vehicles)	5,715	49.14
49331	Freight transport by specialised vehicles	1,554	13.36
52299	Other transportation support activities not elsewhere classified (activities of air cargo agents; activities of customs agents…)	1,287	11.07
50221	Inland freight water transport by motor vehicles	433	3.72
52291	Shipping agency/freight forwarding services	401	3.45
52292	Logistics, including: planning, designing and supporting operations of transportation, warehousing and distribution	400	3.44
52109	Warehouses and storage of goods in other warehouses	306	2.63
49339	Land freight transport by other means	284	2.44
53200	Courier activities	267	2.3
52242	Motorway cargo handling	151	1.3
50121	Coastal freight water transport	149	1.28
49333	Freight transport by other motor vehicles	145	1.25
52259	Service activities incidental to land transport	130	1.12
52222	Service activities incidental to sea and coastal transportation	60	0.52
52101	Warehouses and storage of goods in bonded warehouses	57	0.49
53100	Postal activities	48	0.41
52244	Inland water cargo handling	44	0.38

Scode 5	Categories of logistics activities	Frequency	Percent
50122	Sea freight water transport	35	0.3
52102	Warehouses and storage of goods in refrigerated warehouses (except bonded warehouse)	34	0.29
52243	Seaway cargo handling	31	0.27
52224	Service activities incidental to inland water transport	29	0.25
52239	Service activities incidental to air transportation	15	0.13
52210	Service activities incidental to rail transportation	12	0.1
49120	Freight rail transport	10	0.09
52221	Operation of harbors	11	0.09
50222	Inland freight water transport by non-motorised vehicles	9	0.08
52223	Operation of inland ports	3	0.03
52241	Railway cargo handling	4	0.03
49400	Transport via pipeline	2	0.02
51209	Other freight air transport	2	0.02
49334	Freight transport by non-motorised vehicles	1	0.01
52245	Air cargo handling	1	0.01
Total		11,630	100

Note: The 5-digit codes is pursuant to the Decision No. 27/2018/QD-TTg, issued on July 06, 2018, by the Prime Minister, concerning "Promulgating Vietnam standard industrial classification".

Source: own elaboration.

References

Admassie, A., & Matambalya, F. A. S. T. (2002). Technical efficiency of small- and medium- scale enterprises: Evidence from a survey of enterprises in Tanzania. *Eastern Africa Social Science Research Review*, *18*(2), 1–29.

Aifuwa, H. O. (2020). Sustainability reporting and firm performance in developing climes: A review of literature. *Copernican Journal of Finance & Accounting*, *9*(1), 9–29. https://doi.org/10.12775/CJFA.2020.001

Akhtar, T. (2022). Corporate governance, excess-cash and firm value: Evidence from ASEAN-5. *Economics and Business Review*, *8*(4), 39–67. https://doi.org/10.18559/ebr.2022.4.3

Al-Matari, E. M., Al-Swidi, A. K., & Fadzil, F. H. B. (2014). The measurements of firm performance's dimensions. *Asian Journal of Finance & Accounting*, *6*(1), 24–49. https://doi.org/10.5296/ajfa.v6i1.4761

Alegre, J., Lapiedra, R., & Chiva, R. (2006). A measurement scale for product innovation performance. *European Journal of Innovation Management*, *9*(4), 333–346. https://doi.org/10.1108/14601060610707812

Ali, A., Alim, W., Ahmed, J., & Nisar, S. (2022, January). *Yoke of corporate governance and firm performance: A study of listed firms in Pakistan*. MPRA Paper. https://mpra.ub.uni-muenchen.de/113579/

Amran, N. A., Yusof, M. 'Atef M., Ishak, R., & Aripin, N. (2014). Do characteristics of CEO and chairman influence government- linked companies performance? *Procedia – Social and Behavioral Sciences*, *109*, 799–803. https://doi.org/10.1016/j.sbspro.2013.12.546

Bantel, K., & Jackson, S. (1989). Top management and innovations in banking: Does the composition of the top team make a difference? *Strategic Management Journal*, *10*, 107–124.

Bellakhal, R., & Mouelhi, R. (2023). Digitalisation and firm performance: Evidence from Tunisian SMEs. *International Journal of Productivity and Quality Management*, *39*(1), 42–65. https://doi.org/10.1504/IJPQM.2023.130872

Boiko, K. (2022). R&D activity and firm performance: Mapping the field. *Management Review Quarterly*, *72*(4), 1051–1087. https://doi.org/10.1007/s11301-021-00220-1

Chege, S. M., Wang, D., & Suntu, S. L. (2020). Impact of information technology innovation on firm performance in Kenya. *Information Technology for Development*, *26*(2), 316–345. https://doi.org/10.1080/02681102.2019.1573717

Chu, Z., Xu, J., Lai, F., & Collins, B. J. (2018). Institutional theory and environmental pressures: The moderating effect of market uncertainty on innovation and firm performance. *IEEE Transactions on Engineering Management*, *65*(3), 392–403. https://doi.org/10.1109/TEM.2018.2794453

De Loecker, J. (2013). Detecting learning by exporting. A*merican Economic Journal: Microeconomics*, *5*(3), 1–21.

Eris, E. D., & Ozmen, O. N. T. (2012). The effect of market orientation, learning orientation and innovativeness on firm performance: A research from Turkish logistics sector. *International Journal of Economic Sciences and Applied Research*, *5*(1), 77–108.

Erjavec, E., Redek, T., & Kostevc, Č. (2023). SMEs "growing smart": The complementarity of intangible and digital investment in small firms and their contribution to firm performance. *Economic and Business Review*, *25*(4), 216–232. https://doi.org/10.15458/2335-4216.1328

European Commission. (2020). *Community innovation survey 2020 (CIS2020)*. https://ec.europa.eu/eurostat/cache/metadata/en/inn_cis12_esms.htm

Gërguri-Rashiti, S., Ramadani, V., Abazi-Alili, H., Dana, L. P., & Ratten, V. (2017). ICT, Innovation and firm performance: The transition economies context. *Thunderbird International Business Review*, *59*(1), 93–102. https://doi.org/10.1002/tie.21772

Guo, X., Li, M., Wang, Y., & Mardani, A. (2023). Does digital transformation improve the firm's performance? From the perspective of digitalization paradox and managerial myopia. *Journal of Business Research*, *163*, 113868. https://doi.org/10.1016/j.jbusres.2023.113868

Gyamera, E., Atuilik, W. A., Eklemet, I., Matey, A. H., Tetteh, L. A., & Apreku-Djan, P. K. (2023). An analysis of the effects of management accounting services on the financial performance of SME: The moderating role of information technology. *Cogent Business & Management*, *10*(1), 2183559. https://doi.org/10.1080/23311975.2023.2183559

Hagel III, J., Seely Brown, J., & Davison, L. (2010). The best way to measure company performance. *Harvard Business Review*. https://hbr.org/2010/03/the-best-way-to-measure-compan

Harris, D., Kew, H., & Taylor, A. M. R. (2020). Level shift estimation in the presence of non-stationary volatility with an application to the unit root testing problem. *Journal of Econometrics*, *219*(2), 354–388. https://doi.org/10.1016/j.jeconom.2020.03.008

Hayes, A. F., & Cai, L. (2007). Using heteroskedasticity-consistent standard error estimators in OLS regression: An introduction and software implementation. *Behavior Research Methods*, *39*(4), 709–722. https://doi.org/10.3758/BF03192961

Hidalgo, A., & López, V. (2009). Drivers and impacts of ICT adoption on transport and logistics services. *Asian Journal of Technology Innovation*, *17*(2), 27–47. https://doi.org/10.1080/19761597.2009.9668672

Huang, B., Cui, Y., & Chan, K. C. (2022). Firm-level financialization: Contributing factors, sources, and economic consequences. *International Review of Economics & Finance*, *80*, 1153–1162. https://doi.org/10.1016/j.iref.2022.04.007

Ince, H., Imamoglu, S. Z., Keskin, H., Akgun, A., & Efe, M. N. (2013). The impact of ERP systems and supply chain management practices on firm performance: Case of Turkish companies. *Procedia – Social and Behavioral Sciences*, *99*, 1124–1133. https://doi.org/10.1016/j.sbspro.2013.10.586

Jang, S. W., & Ahn, W. C. (2021). Financial analysis effect on management performance in the Korean logistics industry. *The Asian Journal of Shipping and Logistics*, *37*(3), 245–252. https://doi.org/10.1016/j.ajsl.2021.06.003

Kittipanya-ngam, P., & Tan, K. H. (2020). A framework for food supply chain digitalization: Lessons from Thailand. *Production Planning & Control*, *31*(2–3), 158–172. https://doi.org/10.1080/09537287.2019.1631462

Koellinger, P. (2008). The relationship between technology, innovation, and firm performance—empirical evidence from e-business in Europe. *Research Policy*, *37*(8), 1317–1328. https://doi.org/10.1016/j.respol.2008.04.024

Kromann, L., & Sørensen, A. (2019). Automation, performance and international competition: A firm-level comparison of process innovation. *Economic Policy*, *34*(100), 691–722. https://doi.org/10.1093/epolic/eiaa002

Le, D. V., Le, H. T. T., Pham, T. T., & Vo, L. V. (2023). Innovation and SMEs performance: Evidence from Vietnam. *Applied Economic Analysis*, *31*(92), 90–108. https://doi.org/10.1108/AEA-04-2022-0121

Lee, H. L. (2000). Creating value through supply chain integration. *Supply Chain. Management Review*, *4*, 30–36.

Long, J. S., & Ervin, L. H. (2000). Using heteroscedasticity consistent standard errors in the linear regression model. *The American Statistician*, *54*(3), 217–224. https://doi.org/10.2307/2685594

Lu, C. S., & Yang, C. C. (2010). Logistics service capabilities and firm performance of international distribution center operators. *The Service Industries Journal*, *30*(2), 281–298. https://doi.org/10.1080/02642060802123392

Mai, T., Dinh, Q., Quach, H., & Nguyen, V. (2023). Performance of Vietnamese shipping firms: A four random components stochastic frontier approach. *Acta Logistica*, *10*(2), 319–329. https://doi.org/10.22306/al.v10i2.397

Masood, O., Aktan, B., & Chaudhary, S. (2009). An empirical study on banks profitability in the KSA: A co-integration approach. *African Journal of Business Management*, *3*(8), 374–382.

Na, K., & Kang, Y. H. (2019). Relations between innovation and firm performance of manufacturing firms in Southeast Asian emerging markets: Empirical evidence from Indonesia, Malaysia, and Vietnam. *Journal of Open Innovation: Technology, Market, and Complexity*, *5*(4), 98. https://doi.org/10.3390/joitmc5040098

Nguyen, X., Le, T., Nguyen, A., Pham, T., & Tran, T. (2021). Supply chain risk, integration, risk resilience and firm performance in global supply chain: Evidence from Vietnam pharmaceutical industry. *Uncertain Supply Chain Management*, *9*(4), 779–796. https://m.growingscience.com/beta/uscm/5013-supply-chain-risk-integration-risk-resilience-and-firm-performance-in-global-supply-chain-evidence-from-vietnam-pharmaceutical-industry.html

Nikaido, Y. (2004). Technical efficiency of small-scale industry: Application of stochastic production frontier model. *Economic and Political Weekly*, *39*(6), 592–597.

Nyaoke, T. A., & Muturi, P. W. (2018). Logistics automation drivers and operational performance of tea processing firms in Kisii county, Kenya. *International Journal of Social Sciences and Information Technology*, *4*(5), 353–369.

Nyeadi, J. D. (2023). Foreign Direct Investment and firm value: Evidence from selected countries in sub-Saharan Africa. *Journal of African Business*, *24*(2), 260–279. https://doi.org/10.1080/15228916.2022.2042079

Ramadani, V., Hisrich, R. D., Abazi-Alili, H., Dana, L. P., Panthi, L., & Abazi-Bexheti, L. (2019). Product innovation and firm performance in transition economies: A multi-stage estimation approach. *Technological Forecasting and Social Change*, *140*, 271–280. https://doi.org/10.1016/j.techfore.2018.12.010

Ramos-Hidalgo, E., Edeh, J. N., & Acedo, F. J. (2022). Innovation adaptation and post-entry growth in international new ventures. *European Research on Management and Business Economics*, *28*(1), 100169. https://doi.org/10.1016/j.iedeen.2021.100169

Romano, J. P., & Wolf, M. (2017). Resurrecting weighted least squares. *Journal of Econometrics*, *197*(1), 1–19. https://doi.org/10.1016/j.jeconom.2016.10.003

Safa, M. S. (2005). Socio-economic factors affecting the income of small-scale agroforestry farms in hill country areas in Yemen: A comparison of OLS and WLS determinants. *Small-Scale Forest Economics, Management and Policy*, *4*(1), 117–134. https://doi.org/10.1007/s11842-005-0008-7

Salim, M. N., & Susilowati, R. (2020). The effect of internal factors on capital structure and its impact on firm value: empirical evidence from the food and beverages industry listed on Indonesian stock exchange 2013-2017. *International Journal of Engineering Technologies and Management Research*, *6*(7), 173–191. https://doi.org/10.29121/ijetmr.v6.i7.2019.434

Sevinç, A., Gür, Ş., & Eren, T. (2018). Analysis of the difficulties of SMEs in Industry 4.0 applications by analytical hierarchy process and analytical network process. *Processes*, *6*(12), 264. https://doi.org/10.3390/pr6120264

Singh, R., Chandrashekar, D., Subrahmanya Mungila Hillemane, B., Sukumar, A., & Jafari-Sadeghi, V. (2022). Network cooperation and economic performance of SMEs: Direct and mediating impacts of innovation and internationalisation. *Journal of Business Research*, *148*, 116–130. https://doi.org/10.1016/j.jbusres.2022.04.032

Skvarciany, V., Jurevičienė, D., & Morkunas, M. (2019). Determinants of bank profitability: Empirical research on Lithuanian market. *International Journal of Economic Policy in Emerging Economies*, *12*(5), 443–452. https://doi.org/10.1504/IJEPEE.2019.104637

Srai, J., Settanni, E., Tsolakis, N., & Aulakh, P. (2019, September 26–27). *Supply chain digital twins: Opportunities and challenges beyond the hype*. 23rdCambridge International Manufacturing Symposium. https://doi.org/10.17863/CAM.45897

Sudrajat, D., Djojo, B. W., Adhikara, C. T., & Kartikasari, D. (2017, November 15–17). *The effect of ownership of logistics physical asset and integrated ICT to innovative capability and its impact on firm performance*. 2017 International Conference on Information Management and Technology. https://doi.org/10.1109/ICIMTech.2017.8273550

Sun, Q., Tong, W. H. S., & Tong, J. (2002). How does government ownership affect firm performance? Evidence from China's privatization experience. *Journal of Business Finance & Accounting*, *29*(1–2), 1–27. https://doi.org/10.1111/1468-5957.00422

Susanti, F. E., Widiyanti, N., & Madyawati, E. (2022). The impact of firm size, leverage, and sales growth on company performance. *Asia Pacific Journal of Business Economics and Technology*, *2*(1), 414–425.

Taouab, O., & Issor, Z. (2019). Firm performance: Definition and measurement models. *European Scientific Journal*, *15*(1), 93–106. https://doi.org/10.19044/esj.2019.v15n1p93

Tsafnat, G., Glasziou, P., Choong, M. K., Dunn, A., Galgani, F., & Coiera, E. (2014). Systematic review automation technologies. *Systematic Reviews*, *3*(1), 74. https://doi.org/10.1186/2046-4053-3-74

Tuan, N., Nhan, N., Giang, P., & Ngoc, N. (2016). The effects of innovation on firm performance of supporting industries in Hanoi, Vietnam. *Journal of Industrial Engineering and Management*, *9*(2), 413–431. https://doi.org/10.3926/jiem.1564

Ul Hassan, M., Shaukat, S., Nawaz, M. S., & Naz, S. (2013). Effects of innovation types on firm performance: An empirical study on Pakistan's manufacturing sector. *Pakistan Journal of Commerce and Social Sciences*, *7*(2), 243–262.

Wade, M., & Hulland, J. (2004). The resource-based view and information systems research: Review, extension, and suggestions for future research. *MIS Quarterly*, *1*, 107–142.

Wang, M. (2016). The role of innovation capability in the Australian courier industry. *International Journal of Innovation Management*, *20*(7), 1650070. https://doi.org/10.1142/S1363919616500705

Wang, M., & Prajogo, D. (2024). The effect of supply chain digitalisation on a firm's performance. *Industrial Management & Data Systems*, *124*(5), 1725–1745. https://doi.org/10.1108/IMDS-09-2023-0629

Wang, M., Wang, B., & Abareshi, A. (2020). Blockchain technology and its role in enhancing supply chain integration capability and reducing carbon emission: A conceptual framework. *Sustainability*, *12*(24), 10550. https://doi.org/10.3390/su122410550

West, M. A., & Farr, J. L. (1990). Innovation and creativity at work. John Wiley & Sons.

Wilson, M. N., Iravo, D. M. A., Tirimba, O. I., & Ombui, D. K. (2015). Effects of information technology on performance of logistics firms in Nairobi county. *International Journal of Scientific and Research Publications*, *5*(4). https://www.ijsrp.org/research-paper-0415.php?rp=P404005

World Bank. (2015). *Small and medium enterprises (SMEs) finance resource document*. World Bank Group.

Zhang, S., Yang, D., Qiu, S., Bao, X., & Li, J. (2018). Open innovation and firm performance: Evidence from the Chinese mechanical manufacturing industry. *Journal of Engineering and Technology Management*, *48*, 76–86. https://doi.org/10.1016/j.jengtecman.2018.04.004

Zhong, S., Qiu, L., & Sun, B. (2020). Internet and firm development. *International Journal of Crowd Science*, *4*(2), 171–187. https://doi.org/10.1108/IJCS-11-2019-0032