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LEVERAGING ICT FOR PRODUCT INNOVATION: INSIGHTS FROM SOUTHEAST ASIAN COUNTRIES

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Abstract

Purpose: Firms are increasingly adapting their operations, strategies, and business models to meet market challenges and strengthen their competitive advantage. The adoption of information and communication technology (ICT) is growing in popularity as it helps firms optimize processes and ensure business continuity in an increasingly dynamic and volatile business environment. Hence, this study explores the impact of information and communication technology (ICT) adoption on product innovation of Southeast Asian firms, focusing on the moderating role of research and development (R&D).

Methodology: This study employed data from five countries—Cambodia, Indonesia, the Philippines, Singapore, and Vietnam—from the 2023 World Bank Enterprise Surveys (WBES). The research employs multilevel logistic regression analysis for the empirical analysis.

Findings: The results indicate that all three ICT dimensions, including (i) Business's own website or social media page, (ii) Electronic payments from customers, and (iii) Exporting directly through electronic means, significantly enhance product innovation. Additionally, R&D positively moderates the relationships between product innovation and both website/social media usage and electronic payments. However, R&D does not moderate the relationship between exporting and innovation through electronic means.

Originality: The study provides policymakers and managers with significant insight into how to foster innovation through technology and R&D investments in Southeast Asia.

Keywords: Website and social media usage; Electronic payment; Electronic exporting; R&D; Product innovation; Southeast Asia

JEL: M15, O32, O53

1. Introduction

Firms are increasingly recognizing the importance of adapting to market challenges in their operations, strategies, and business models, leveraging competitive advantages (Loureiro, Ferreira, & Simões, 2021). The adoption of information and communication technology (ICT) helps firms optimize and enhance the effectiveness of their processes, ensuring business continuity (Heredia et al., 2022; Parwita et al., 2021). Consequently, ICT adoption is becoming increasingly prevalent in a dynamic, volatile environment.

A stream of studies has shown that ICT capabilities enhance firms by reducing costs and increasing flexibility (Ferreira, Fernandes, & Veiga, 2024; Fitzgerald, Kruschwitz, Bonnet, & Welch, 2014; Martínez-Caro, Cegarra-Navarro, & Alfonso-Ruiz, 2020). Additionally, ICT adoption contributes to sustainable competitive advantages by enabling the development of more complex and superior strategies (Cirillo, Fanti, Mina, & Ricci, 2023). Digital technologies are influencing nearly every economic sector in various ways by establishing new markets for innovative products and altering manufacturing and distribution systems (Romero & Mammadov, 2024; Gajdzik, 2024). When firms implement ICT, they strategically modify their value-creation approaches (Vial, 2019). Thus, for companies, ICT applications promote product development, production processes, and business organizations, which implies an innovation opportunity for a company (Cuevas-Vargas, Aguirre, & Parga-Montoya, 2022; Kurniawati et al., 2020; Kohli & Melville, 2019).

However, some literature suggests that ICT capabilities have a limited impact on firms' innovation performance. Specifically, Usai et al. (2021) discussed the notion that

innovative outcomes require constant efforts, creativity, and investments in R&D activities, rather than the adoption of technological capabilities. Additionally, Tan, Pan, and Hackney (2010) also noted that technological and digital capabilities alone are insufficient for achieving successful innovation performance.

A stream of studies has widely accepted the conceptualization of product and process innovation, in which R&D is the primary input for innovation (Higón, 2012; Kleis, Chwelos, Ramirez, & Cockburn, 2012). The investment in R&D activities enhances firms' absorptive capacity to acquire new knowledge, thereby strengthening the impact of ICT on innovation (Ballot & Taymaz, 1997; Zhou, Yang, Liu, & Gong, 2023). Moreover, R&D also helps firms identify technological opportunities to contribute to innovative activities (Lei, Tang, Zhao, & Chen, 2024).

ASEAN is the third-largest regional economy in Asia and the fifth-largest worldwide (ASEAN, 2023). The Philippines (53rd) and Indonesia (54th) approach the top 50, with Indonesia exhibiting one of the most significant upward movements in the Global Innovation Index over the past three years (Dutta, Lanvin, León, & Wunsch-Vincent, 2024). Moreover, Southeast Asia is the most rapidly expanding internet market globally, with 125,000 new users using the Internet daily (Akaima, 2024). However, current studies primarily focus on developed countries or European markets (Ferreira et al., 2024; Heredia et al., 2022) because these countries have sufficient financial resources to adopt technology and digital capabilities. Hence, this study aims to investigate the impact of ICT capabilities on product innovation in the ASEAN context. Moreover, the moderating role of R&D in the ICT adoption–product innovation relationship is also investigated.

The paper makes two main contributions to innovation literature. Firstly, technological and digital adoption has rapidly grown in ASEAN countries, which enhances innovation (Dutta et al., 2024). The technological application promotes knowledge sharing (Wei, Xu, & Liu, 2022) and internal communication (Ferreira et al., 2024), enhancing product and process innovation to achieve better business performance. However, most research discussing the role of digital capabilities in innovation has focused on developed countries. There has been no study on this topic in developing economies. Therefore, this study aims to address this gap.

Secondly, the investment in R&D activities enhances firms' absorptive capacity, which allows employees to acquire new knowledge, leading to firms' innovation (Ben Khalifa, 2023; Vega-Jurado, Gutiérrez-Gracia, & Fernández-de-Lucio, 2008). Particularly, employees access more technological information, which fosters digital adoption in innovation (González, Miles-Touya, & Pazó, 2016). Moreover, firms also rapidly identify market opportunities to adopt new technological tools, leveraging innovative activities (Harris & Li, 2009). However, there is probably no study investigating the moderating role of R&D in the ICT – innovation relationship. Thus, this study is probably the first attempt to investigate the moderating role of R&D on the relationship between ICT and product innovation.

The remaining paper is structured as follows: Section 2 focuses on literature reviews to develop hypotheses. Section 3 discusses the data and empirical methods. Section 4 presents

the results and discussions. Section 5 presents the conclusions and managerial implications. Finally, Section 6 presents the limitations and future research directions.

2. Literature review and hypothesis development

The Resource-Based View (RBV) theory posits that firms can establish a competitive advantage by cultivating strategic competencies that are scarce, highly valued, difficult to replicate, and cannot be imitated or transmitted, with no substitutes (Barney, 1991; El-Kassar & Singh, 2019). Following the resource-based perspective, firms can differentiate based on their ICT resources, which subsequently generate firm-specific capabilities and contribute to a sustained competitive advantage (Demianchuk, Koval, Hordopolov, Kozlovtseva, & Atstaja, 2021; Luo & Bu, 2016). Several studies pointed out that ICT contributes to firms' innovative activities (Higón, 2012; Karakara & Osabuohien, 2020; Ollo-López & Aramendía-Muneta, 2012). By adopting new information technology, firms can access specialized knowledge and other innovation components to integrate into new products, services, and processes (Kawakami, Durmuşoğlu, & Barczak, 2011). In addition, digital technologies not only reduce barriers to transmitting knowledge but also generate new knowledge, enabling the innovation of new products or processes (Ollo-López & Aramendía-Muneta, 2012). For example, firms may acquire knowledge through their retail websites and other communication technologies employed during consumer interactions to promote innovation (Kleis et al., 2012). Therefore, the adoption of information technologies can enhance a firm's innovation ability by applying state-of-the-art technologies to its business.

In a resource-based view, firms can enhance their organizational capacity by adopting various technologies and digital assets, such as websites, social media pages, electronic means, and e-payment systems (Higón, 2012; Kawakami et al., 2011; Parwita et al., 2021). These applications can help firms access different approaches to enhance product innovation. Firstly, websites and social media pages play a crucial role in operating businesses and connecting with customers in the digital era (Kleis et al., 2012; Prandelli, Verona, & Raccagni, 2006). A stream of studies revealed that through these means, firms can capture market demand and transform it into knowledge, leading to new product development (Kawakami et al., 2011; Kleis et al., 2012; Ollo-López & Aramendía-Muneta, 2012). The lack of clarity regarding future market demands for new items is a significant hindrance to companies allocating resources towards innovation (Higón, 2012). Hence, firms can gather user feedback and discussions on social media pages to understand customer insights, which in turn lead to product innovation (Leenders & Dolfsma, 2016). Furthermore, it is easier for both the company and its consumers to address complaints online from social media pages. The accurate analysis of complaints can enhance current products and may even result in significant improvements (Du, Yalcinkaya, & Bstieler, 2016).

Additionally, business websites contribute to increasing consumer trust, allowing them to share information (Urban & Hauser, 2004) easily. Specifically, websites may increase

consumer involvement to generate ideas for new product development (Prandelli et al., 2006). Some studies pointed out that this may prevent wasteful investment and adapt to customers' needs, leading to product innovation (Higón, 2012; Karakara & Osabuohien, 2020; Prandelli et al., 2006). Subsequently, firms create business websites where users interact with products by selecting features and customizing the characteristics of those products. For example, Volvo has established a website, Conceptlabvolvo.com, where users can select their preferred new automobile concepts (Prandelli et al., 2006). Therefore, firms can innovate products based on customer choices, which enhances product adaptability in uncertain markets.

Based on the above arguments, the following hypothesis is proposed.

H1: The Business's website or social media page is positively related to product innovation.

Electronic payments increase the internal sales performance of products, which helps firms identify market trends to improve their products (Al-Sabaawi, Alshaher, & Alsalem, 2023; Kilay, Simamora, & Putra, 2022). Specifically, firms may recognize valuable customer insights in product preferences (See-To, Papagiannidis, & Westland, 2014), purchase tendencies (Yu, Peng, & Wang, 2023), and spending patterns (Al-Sabaawi et al., 2023). Based on transaction data, organizations can monitor emerging trends or fluctuations in consumer demand (Adhikary, Diatha, Borah, & Sharma, 2021). Moreover, a stream of studies has indicated that electronic payment provides real-time data, offering personalization (Adhikary et al., 2021; Kumar, Nim, & Sharma, 2019). This characteristic enables businesses to rapidly adapt to consumer preferences, which can drive product innovation by facilitating dynamic adjustments to products (Wen, Yeh, Tsai, Peng, & Shuai, 2018). The real-time tracking of electronic payment also allows firms to be more agile in product development by constantly monitoring customers' responses to purchase behavior (Wonglimpiyarat, 2014). Additionally, electronic payment systems often integrate with other systems, such as inventory management and CRM systems, to facilitate more efficient product development by enhancing business operations (Chen, Li, Wu, & Luo, 2017). System integration offers a combination of different metrics that enables managers to foster product innovation based on market data and customer insights (Hernandez-Vivanco, Bernardo, & Cruz-Cázares, 2018). Thus, we hypothesize:

H2: Using electronic payments from customers is positively related to product innovation.

Third, exporting directly through electronic means is that firms sell the product or service to the international market through e-commerce or other e-networks (Sun, 2021). Customers in each market may require different standards of products, such as environmental level, package design, and product characteristics (Lecerf & Omrani, 2020).

Therefore, firms may adjust and improve their products to match customers' demands, leading to product innovation. Moreover, firms receive feedback and reviews from international customers through e-commerce and other electronic channels, and they customize products to achieve customer satisfaction, leading to improved business performance (Afanasyev, Hanechko, Trubei, & Lukhanina, 2024; Luo, . The uncertainty and heterogeneous preferences in different markets may promote product innovation, and firms measure it by collecting customer responses through electronic networks (Paunov & Rollo, 2016). Some studies found that investment in e-commerce may enhance new product development (Pan, Li, Liu, & Zhang, 2020; Sun, 2021). Firms that want to export to other countries must ensure that their products adapt to market characteristics, such as local cultures, behaviors, and customer preferences (Lecerf & Omrani, 2020). Thus, firms create and develop products for each market.

Drawing from the arguments discussed above, the following hypothesis is proposed:

H3: Exporting directly through electronic means is positively related to product innovation.

Several studies have examined the moderating effect of some variables on the relationship between ICT and innovation activities. For example, the moderating influence of service R&D team structure in the information technology and product-process innovation relationship (Vendrell-Herrero, Bustinza, & Opazo-Basaez, 2021), the moderating impact of democracy levels and political systems on the relationship between ICT – innovation (Xiong, Zang, & Gao, 2022), the moderating role of technological capabilities and resources in digital technology adoption and innovation performance relationship (Zhou et al., 2023). However, prior studies have not discussed the moderating effect of R&D in ICT – the innovation relationship. The engagement in R&D generally developed absorptive capacity (Cohen & Levinthal, 1990), enabling the identification and exploitation of internal knowledge (Rothaermel & Alexandre, 2009). Therefore, this study explores the role of R&D as a mechanism for enhancing absorptive capacity.

Absorptive capacity is defined as "a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128). Absorptive capacity plays a crucial role in moderating the relationship between ICT and product innovation. Specifically, absorptive capacity enhances a firm's ability to leverage state-of-the-art ICT technologies and apply them to innovation activities (Martinez-Sanchez, Perez-Perez, & Vicente-Oliva, 2019). Knowledge acquisition and assimilation capabilities are established through external technology sourcing, while knowledge transformation and exploitation capabilities are generated as a consequence of internal technology sourcing (Rothaermel & Alexandre, 2009). Therefore, a firm's absorptive capacity enables it to establish a connection between internal and external technology sourcing, thereby facilitating product renovation (Cuevas-Vargas et al., 2022).

Investment in R&D activities enhances a company's absorptive capacity to incorporate

and implement external knowledge, such as data from digital platforms, thereby enhancing the effectiveness of innovation (Hall, Francesca, & Mairesse, 2013). Overall, absorptive capacity has a positive influence on the impact that ICT has on firms' innovation performance.

Stronger R&D activities may enhance business performance, based on both internal and external data (Berchicci, 2013; De Luca, Verona, & Vicari, 2010). The implementation of websites and social media pages provides digital data, including customer responses, social discussions, and customer sentiment (Al-Shami et al., 2021). R&D teams may translate them into valuable insights for business activities. Based on the collected customer preferences, firms can redesign or renovate their products (Harris & Li, 2009). In particular, social media and websites provide real-time insights into consumer preferences (Scuotto, Del Giudice, & Carayannis, 2017). By leveraging these trends, R&D can anticipate market changes and develop products that align with future demand (Blackburn, Jeffrey, David, & Klabjan, 2017).

Building on the above reasoning, the following hypothesis is advanced.

H4: R&D positively moderates the business's own website or social media page - product innovation relationship.

From the resource-based view, to enhance innovation, R&D integrates with other assets, such as payment data and digital knowledge, to leverage competitive advantages (Henard & McFadyen, 2012). The interaction between R&D and electronic payments may enhance firms' capabilities for innovation outcomes (Adhikary et al., 2021). Moreover, electronic payment is considered a dynamic capability to adapt to the changes of consumer behavior and market demand (Li, McAndrews, & Wang, 2020). R&D may help absorb valuable insights from payment data to strengthen product innovation. Electronic payments facilitate real-time transactions, enabling firms to understand customer behavior and market needs better (Wen et al., 2018; Yu et al., 2023). R&D investment offers a sophisticated method for analyzing payment insights, leading to product innovation (Widayat, Masudin, & Satiti, 2020). For example, the R&D department may develop a machine learning model to monitor and analyze electronic sales data (Kim, 2023), which can help understand customer behavior and improve the product accordingly.

Based on the above arguments, the following hypothesis is proposed.

H5: R&D positively moderates the relationship between the use of electronic payments by customers and product innovation.

According to the widely recognized "learning-by-exporting" perspective, the majority of studies indicate that exporting improves innovation performance (Golovko & Valentini, 2014; Nguyen-Van & Chang, 2021; Xie & Li, 2018). In particular, exporting serves as a mechanism for accumulating external knowledge, enabling exporters to acquire or adopt

new production technologies through their interactions with more knowledgeable stakeholders (Nguyen-Van & Chang, 2021). Exporting through electronic means enables firms to access external knowledge from international customers, and it requires them to absorb this knowledge rapidly in order to innovate their products (Lecerf & Omrani, 2020). Online exporting can provide a rapid response from global markets, yielding valuable insights (Zhang & Liu, 2023). Then, R&D offers the knowledge, resources, and methodologies to evaluate this information and create new products (Harris & Li, 2009). Additionally, higher R&D investment creates more resources, such as skilled personnel, technologies, and cognitive knowledge to pursue innovation to meet global market demands (Aw, Roberts, & Xu, 2011).

Given the rationale presented above, the following hypothesis is formulated.

H6: R&D positively moderates the exporting directly through electronic means - product innovation relationship.

Based on the above hypothesis development, Figure 1 summarizes the proposed research framework, which includes six hypothesized relationships.

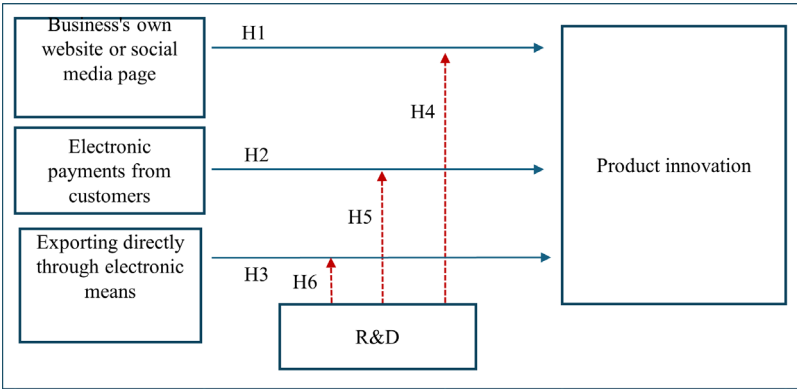

Figure 1: Research framework

3. Data and research methods

3.1 Data

This study utilizes data from the World Bank Enterprise Survey (WBES), a program sponsored by the World Bank that collects firm-level data on corporations worldwide consistently. The aim is to gather general information about business environments and the problems enterprises face. The WBES encompasses a wide range of topics, including

business performance, ICT adoption, administrative procedures, the relationship between businesses and government agencies, workforce skills and qualifications, technology adoption, investment in research and development, and innovation activities. The WBES covers more than 219,000 firms in 159 economies (World Bank, 2024).

The study uses the most recent data from WBES (the survey year 2023) for five selected Southeast Asian countries (i.e., Cambodia, Indonesia, the Philippines, Singapore, and Vietnam). Data in the survey year 2023 are not available for other countries at the time of conducting this research. The final dataset, after excluding outliers, comprises approximately 3,000 observations.

3.2 Research method

Dependent variable

The key dependent variable in this study is *Product innovation*. Following prior studies (Chang & van, 2021; Nguyen-Van & Chang, 2020), *Product innovation* is constructed as a dummy variable, which is assigned the value of "1" if the firm introduced new or improved products or services during the last three years. *Product innovation* takes the value of "0" if the firm did not perform the above-mentioned activities.

Independent variables and moderators

Three variables, namely *the Business's website or social media page, Electronic payments from customers, and exporting directly through electronic means,* act as proxies for ICT adoption in this study (Kasseeah, 2024). The variable *Business's website or social media page* is operationalized as a dummy variable, which is equal to "1" if the firm has its own website or social media page. It is coded as "0" otherwise (Kasseeah, 2024). The variable *Electronic payments from customers* is a continuous variable, which represents the percentage of total sales or transactions paid electronically by customers (Abdulkarem & Hou, 2022). The variable *Exporting directly through electronic means*. This takes the value of "1" if the firm sells its products or services directly to international customers via electronic platforms, such as e-commerce websites or online marketplaces, and "0" otherwise.

The moderator in this study is *R&D*. We obtain the information for R&D activities from the question "Did this establishment spend on research and development activities, either in-house or contracted with other companies, excluding market research surveys?". The variable *R&D* is constructed as a dummy variable, which takes the value of "1" if the firm answered "Yes" to the above question, and "0" otherwise (Anzola-Román, Bayona-Sáez, & García-Marco, 2018; Nguyen-Van & Chang, 2020).

Control variables

Firm age: In this study, a firm's age is calculated by taking the logarithm of its years of operation (Dwibedy, 2022; Zhang & Xiaofeng, 2023).

Firm size: By calculating the logarithm of the number of full-time employees, the

research creates an assessment of a company's size (Audretsch, Belitski, & Brush, 2022; Nguyen, 2022).

Industry: The study considers the type of industry in which a firm was registered as its primary business, classified under a two-digit manufacturing industry. According to the "International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4" published by the United Nations Statistical Division in 2008, there are a total of 24 two-digit manufacturing industries included in this study. The two-digit codes range from 10 to 33. Consequently, a categorical variable named *Industry* is constructed, which comprises 24 distinct levels, each corresponding to one of the 24 two-digit manufacturing industries (Chang & Nguyen-Van, 2021; Nguyen-Van & Chang, 2020).

Country: The study also accounts for the country effect in five selected countries in Southeast Asia, including Cambodia, Indonesia, the Philippines, Singapore, and Vietnam. A categorical variable called *"Country" is created, with five values corresponding to the five countries (Nguyen-Van & Chang, 2020; Nguyen-Van*.

Empirical methods

The study uses data from the WBES for Cambodia, Indonesia, the Philippines, Singapore, and Vietnam, so the dataset will be hierarchical. Specifically, enterprises are level 1, the main industry is level 2, and countries are level 3. The study uses a multilevel mixed-effects logistic regression to perform the quantitative analysis. Multilevel mixed-effects logistic regression analysis is a powerful tool for analyzing hierarchical or clustered data. It allows the proper adjustment of within-cluster dependence and between-cluster variation (Hox, Moerbeek, & Van de Schoot, 2017; StataCorp, 2019).

The mixed-effects multilevel logistic regression method has the advantage of taking into account data with a clustered or hierarchical structure (i.e., firms nested within industrial sectors, sectors nested within countries) compared to the conventional logistic regression method (which does not handle the issue effectively). In Stata, the command "*melogit*" is employed to estimate the mixed-effects multilevel logistic regression (StataCorp, 2019).

4. Findings and discussions

4.1 Descriptive statistics

Table 1 displays the descriptive statistics, utilizing a total sample size of approximately 3,000 observations. It is important to note that we have limited observations for some variables due to missing data: only 332 firms reported on exporting directly through electronic means, and 1,731 firms provided data on electronic payments from customers. Indeed, many firms did not respond to these questions.

The findings indicate that, on average, about 9.1% of the firms engage in product innovation. About 51.5% of the firms have their own website or social media page. The mean percentage of electronic payments received from customers is more than 56%. Moreover,

around 31.3% of the firms engage in direct exporting through electronic means. However, only 3.8% of the firms are involved in R&D activities.

Table 1: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Product innovation	2,888	0.091	0.288	0	1
Business's own website or social media page	2,908	0.515	0.500	0	1
Electronic payments from customers	1,731	56.226	37.329	0	100
Exporting directly through electronic means	332	0.313	0.465	0	1
R&D	2,864	0.038	0.191	0	1
Firm age (ln)	2,922	2.646	0.704	0	4.443
Firm size (ln)	2,922	3.346	1.506	0	9.393

The correlations between the study's independent and control variables are shown in Table 2. Since all correlations among the independent and control variables are less than the threshold value of 0.5, multicollinearity is not a concern for our study (Dormann et al., 2013).

Table 2: Correlation matrix

	1	2	3	4	5	6
Business's website or social media page	1					
Electronic payments from customers	0.132***	1				
Exporting directly through electronic means	0.035	-0.112**	1			
R&D	0.108***	0.013	0.028	1		
Firm age (ln)	0.097***	-0.143***	0.030	0.033*	1	
Firm size (ln)	0.340***	0.295***	0.027***	0.119***	0.084***	1

*Notes: *** $p < 0.01$., ** $p < 0.05$, * $p < 0.1$.*

4.2 Empirical results

Table 3 presents the findings from the multilevel mixed-effects logistic regression analysis, which spans six models, to test the proposed hypotheses. Models 1, 2, and 3 examine the direct effects of three key independent variables—having a business website or social media page, receiving electronic payments from customers, and exporting directly via electronic means—on the probability of product innovation. This research uses Model 4 to test if R&D can moderate the relationship between having a website or social media page and product innovation. Model 5 further examines whether R&D acts as a moderator for the relationship between electronic payments obtained from customers and product innovation. Finally, the study investigates if there is any moderating impact of R&D on the relation between exporting directly via electronic means and product innovation in Model 6.

Table 3 also presents the likelihood ratio (LR) test comparing multilevel mixed-effects logistic regression models with traditional binomial logistic regression models under different specifications (Models 1 to 6). The results of the LR test reveal that for almost all these models, i.e., models 1, 2, 3, 4, and 5, multilevel mixed-effects logistic regression significantly outperforms traditional binomial logistic regression. However, the LR test of Model 6 does not indicate improvement; in other words, the increase in complexity of the multilevel approach for this model is not worth the trouble of the simpler logistic regression.

Regarding hypothesis testing, first, as can be seen from Model 1, the coefficient of having a business website or social media page is statistically significant and positive. This suggests that firms with their own websites or social media pages are more likely to engage in product innovation, providing strong empirical evidence to support Hypothesis 1. The finding validates the RBV perspective. Indeed, ICTs, such as websites or social media channels, constitute crucial means to support innovation. Digital platforms enable firms to understand market demand and consumer preferences, which, in turn, convert this information into substantial knowledge that assists in developing new products (Kawakami et al., 2011; Ollo-López & Aramendía-Muneta, 2012). Direct interaction with customers enables businesses in Southeast Asian countries to gather feedback, complaints, and discussions that provide deep insights into consumer needs, which helps improve existing products or develop new ones based on market demands (Du et al., 2016; Leenders & Dolfsma, 2016).

Moreover, these platforms foster customer trust, which promotes increased information exchange and participation in the product development process. Such participation can lead to innovative product features that more effectively align with customer expectations (Prandelli et al., 2006). In addition, by utilizing these digital tools, companies in Southeast Asian economies can mitigate the risks associated with innovation by avoiding unnecessary investments and focusing on products that genuinely meet consumer needs. This focused approach better aligns the innovation process and amplifies the likelihood of successful product introductions, thereby further enhancing the company's competitive edge (Higón, 2012; Karakara & Osabuohien, 2020; Prandelli et al., 2006).

Second, concerning the impact of electronic payments from customers on product

innovation, the coefficient of electronic payments from customers is positive and significant in Model 2. This supports Hypothesis 2 strongly. The result supports the argument that consumer behavior, particularly when it relates to electronic payment systems, has significant potential to influence a firm's innovation strategies (Kilay et al., 2022). As consumers increasingly adopt electronic payment methods, organizations are compelled to upgrade and enhance their electronic payment systems, often leading to product innovations (Widayat et al., 2020). Specifically, the increased adoption of electronic payments fuels product innovation directly, forcing firms in Southeast Asian countries to continuously change and refine their offerings in response to evolving customer needs (Alam, Awawdeh, & Muhamad, 2021).

Table 3: Estimation results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Business's own website or social media page	0.905***			0.774***		
	(0.165)			(0.168)		
Electronic payments from customers		0.010***			0.006**	
		(0.003)			(0.003)	
Exporting directly through electronic means			2.308***			1.874***
			(0.586)			(0.616)
Business's own website or social media page x R&D				1.831***		
				(0.670)		
Electronic payments from customers x R&D					0.056***	
					(0.013)	
Exporting directly through electronic means x R&D						17.817
						(5031.483)

R&D	3.828***	2.768***	1.301**	2.957***	-0.264	-15.963
	(0.293)	(0.301)	(0.591)	(0.416)	(0.772)	(5031.483)
Firm age (ln)	0.044	0.002	0.615	0.044	0.003	0.751*
	(0.108)	(0.129)	(0.414)	(0.109)	(0.131)	(0.446)
Firm size (ln)	0.092	0.051	-0.020	0.093	0.093	-0.073
	(0.056)	(0.067)	(0.188)	(0.057)	(0.068)	(0.185)
Constant	-3.696***	-3.463***	-5.599***	-3.606***	-3.342***	-5.450***
	(0.524)	(0.577)	(1.689)	(0.527)	(0.591)	(1.824)
Country (var(_con)	0.737	0.753	0.831	0.748	0.816	0.793
	(0.661)	(0.695)	(0.903)	(0.667)	(0.731)	(0.968)
Country > Industry (var(_con)	0.197	0.245	4.80e-32	0.194	0.245	0.018
	(0.095)	(0.124)	(2.76e-16)	(0.095)	(0.124)	(0.709)
Wald	201.49	105.09	22.49	152.32	71.45	23.07
Prob >	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LR test versus the logit model	x^2=47.77 Prob > x^2=0.0000	x^2=35.77 Prob > x^2=0.0000	x^2=2.62 Prob > x^2=0.0528	x^2=47.17 Prob > x^2=0.0000	x^2=36.75 Prob > x^2=0.0000	x^2=3.05 Prob > x^2=0.2171
N	2,840	1,711	329	2,840	1,711	329

*Notes: Standard errors in parentheses. *** p < 0.01., ** p < 0.05, * p < 0.1.*

Third, the coefficient of *Exporting directly through electronic means* is also positive and highly significant, supporting Hypothesis 3 strongly. The result validates the argument that the key benefit of exporting through an electronic medium is the ability to receive prompt responses and feedback from foreign buyers (Luo et al., 2005). E-commerce sites, as well as electronic modes of communication, provide direct access to customer feedback and preferences, which is immensely useful for understanding the demand for a particular segment. This quick feedback mechanism allows the company to adjust its products to suit customers' expectations better quickly (Pan et al., 2020; Sun, 2021). This puts the firms that can successfully utilize this feedback in a better position to innovate more rapidly and enhance their ability to compete in the global market (Lecerf & Omrani, 2020).

Furthermore, the intrinsic uncertainty of international markets, especially in a heterogeneous region like Southeast Asia, is a stimulus for innovation (Jahanger, Usman, Murshed, Mahmood, & Balsalobre-Lorente, 2022). Specifically, electronically exporting firms must address numerous complexities related to customer preferences and market conditions (Katsikeas, Leonidou, & Zeriti, 2020). This compels businesses to innovate in order to address the risks and increasing demands of various markets. Firms can receive an accurate

measure of market reactions to their products by continuously collecting and analyzing consumer responses through electronic networks, and thus achieve continuous innovation (Xu, Yu, Zhang, & Zhang, 2023).

Fourth, the coefficient of the interaction term *Business's own website or social media page* x *R&D* is significant and positive in Model 4. This indicates that R&D positively moderates the relationship between the business's own website or social media page and product innovation, providing strong evidence to support Hypothesis 4. The results provide support for the moderating role of R&D through the absorptive capacity mechanism. In particular, R&D investment significantly strengthens absorptive capacity by elevating the educational level of the workforce, enabling employees to identify market opportunities more readily, quickly understand new knowledge, and adapt to technological changes (Cohen & Levinthal, 1990). Moreover, R&D-related training programs equip employees with the skills to access and transform technological knowledge into innovative products, particularly important in rapidly evolving ICT environments where employees must continuously update their knowledge and skills (Banerjee, 2013). Indeed, employees with enhanced knowledge and skills can effectively utilize digital channels such as websites and social media platforms (Higón, 2012; Karakara & Osabuohien, 2020). Well-educated employees can also analyze customer data to develop market insights, identify innovation opportunities based on customer feedback, transfer knowledge from digital channels to product development processes, and apply their digital literacy to improve the efficiency of these platforms (Capozza & Divella, 2019). Through these mechanisms, R&D investment strengthens the positive impact of ICT on product innovation.

Fifth, the coefficient of the interaction term *Electronic payments from customers* x *R&D* is significant and positive in Model 5. This means that R&D positively moderates the electronic payments from customers-product innovation relationship, supporting Hypothesis 5 strongly. The finding validates the argument that non-cash payment systems necessitate new features in digital products, such as banking apps and e-wallets, a trend particularly pronounced in Southeast Asia (Teng & Khong, 2021). The region has witnessed rapid growth in the acceptance of digital payments—symbolized by programs like GrabPay, GoPay, and ShopeePay—due to a technologically savvy youth base and high mobile penetration rate (Sun & Rizaldy, 2023). Such programs require constant innovation to meet the intricate customer requirements, such as integrating cross-border payments or serving unbanked users, which necessitates employees who possess digital qualifications (Lee, Gan, & Liew, 2022).

In this context, R&D training enhances firms' ability to integrate electronic payment knowledge into product development, enabling the design of functionalities such as QR code payments or reward schemes that cater to Southeast Asian preferences (Turban, Pollard, & Wood, 2021). Furthermore, this enhances firms' absorptive capacity to keep pace with evolving payment trends, such as the trend towards interoperable digital wallets, an ASEAN financial integration objective (Braunerhjelm & Henrekson, 2023). Thus, in Southeast Asia's fast-evolving digital economy, R&D is a key driver of innovation to stay ahead of

the region's dynamic payments landscape.

Finally, the coefficient of the interaction term *"Exporting directly through electronic means" x "R&D"* is not significant in Model 6. This means that R&D does not moderate the exporting directly through electronic means – innovation nexus, which indicates that Hypothesis 6 is not supported. There are several possible reasons for this insignificant relationship. First, the majority of ASEAN economies in this analysis (except Singapore) manufacture standardized or low-tech products for exporting (Zhong & Su, 2021). In such cases, the role of R&D in enhancing product innovation might be limited because these products typically do not require advanced R&D efforts to maintain a competitive advantage in the market. Second, the scale and scope of exporting directly through electronic methods may not be large enough to gain the benefits from R&D investment. Without significant e-export scales, the R&D potential to drive innovation may be reduced, as companies may not fully leverage their R&D capabilities in the context of e-export activities (Huang, Liou, & Iwaki, 2021).

5. Conclusions and implications

ICT implementation is crucial for firm innovation, as it enhances productivity and collaboration, thereby improving market coverage and flexibility. The use of ICT enables companies to streamline their operations, make informed decisions based on data, engage customers more effectively, and establish innovative new business models. Hence, this study investigates the role of ICT adoption on firm innovation in five selected Southeast Asian countries (i.e., Cambodia, Indonesia, the Philippines, Singapore, and Vietnam). The study utilizes data from the World Bank Enterprise Survey, comprising approximately 3,000 observations, and employs multilevel mixed-effects logistic regression for quantitative analysis.

The findings indicate that the adoption of ICT (i.e., a business's website or social media page, electronic payments from customers, and exporting directly through electronic means) has a favorable impact on firm-level product innovation. Moreover, R&D positively moderates the relationships between product innovation and two factors: (i) the use of a business's own website or social media page, and (ii) the acceptance of electronic payments from customers.

The findings suggest that a business's website or social media presence has a positive impact on product innovation. Electronic payments from customers also positively influence new product development. The result highlights the favourable impact of exporting directly through electronic means on firm-level product innovation. Furthermore, R&D positively moderates the relationship between the business's website or social media page and product innovation. R&D also positively moderates the use of electronic payments by customers - a nexus of product innovation. However, R&D does not moderate the exporting relationship through electronic means and innovation.

Based on the results of this study, several managerial implications are proposed. First, because innovation is a crucial driving force for product development, managers should prioritize the adoption of ICT in their firms. This enables firms to gain better insights into market demands and consumer behavior, which can be translated into innovative products and services through investments in technologies such as business websites, social media pages, and electronic payment systems. Such strategic use of ICT supports both product development and the strengthening of a firm's competitive advantage in the market.

Second, managers should also invest in R&D activities as a means of fully realizing the innovative potential of ICT. The results reveal that R&D activities play a significant role in moderating the relationship between ICT adoption and product innovation, particularly in the context of utilizing business websites or social media, as well as electronic payments. With increased R&D, the firm's absorptive capacity also increases. Through this process, managers are better prepared and positioned within an organization to assimilate new technologies into their innovation processes, therefore creating more successful and effective product development.

Third, managers should focus more on developing digital literacy in employees through focused training programs. Innovation will only be possible when employees can use and integrate digital technologies into work processes. Educated and digitally literate employees are better equipped to analyze data from digital platforms, understand customer needs, and identify opportunities for product innovation. Hence, investing in the education and training of employees can increase their potential to contribute to innovation.

6. Limitations and future research directions

The analysis utilizes data from the World Bank Enterprise Survey (WBES), fielded in 2023, which limits the research to a specific point in time and does not effectively reflect the long-term impact of ICT on innovation. This limitation may reduce the study's ability to detect ongoing changes in technology use and innovation patterns over time. Hence, subsequent investigations may address this limitation by integrating longitudinal data, thereby facilitating the analysis of trends and fluctuations in ICT adoption and its influence on innovation.

Since the WBES provides only three proxies for ICT adoption, this study employs three specific indicators: a business's website or social media page, electronic payments from customers, and exporting directly through electronic means. This limits the possibility of a comprehensive understanding of how various digital technologies affect innovation processes in companies. Indeed, other important dimensions of ICT adoption could influence innovation in firms, such as the adoption of advanced manufacturing technologies, cloud computing, or big data analytics. This is a gap that future research could bridge by using a wider scope of ICT adoption measures using a more comprehensive survey. Moreover, incorporating variables regarding the use of artificial intelligence, machine learning, or

blockchain in business processes may also provide a better understanding of how ICT adoption enhances firm innovation.

Moreover, the current study takes into account R&D as a dummy variable due to data constraints. Future study with a more comprehensive survey could measure R&D intensity (e.g., the volume of investment in R&D) to provide deeper insights into its role in moderating the ICT-innovation relationship. Additionally, future studies should analyze the level of digital infrastructure in the country, such as broadband penetration, 5G availability, and digital policy frameworks, to better understand how these factors shape firms' ability to leverage ICT for innovation.

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