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The Nexus of ICT, Manufacturing Productivity and Economic Restructuring in Vietnam*

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Abstract

The objective of this paper is to clarify the relationship between ICT application and labor productivity in Vietnamese manufacturing firms and connect it with the context of economic restructuring in Vietnam. The study uses data of 3,428 manufacturing firms from the General Statistics Office of Vietnam and regression models. In addition to the general model, the study also runs the models for sub-samples of firms of different production technology levels. Research results show two main points. First, information technology can enhance the labor productivity of Vietnamese manufacturing firms. This is true for both ICT hardware applications, ICT services, ICT software solutions, and employees' ICT skills in firms. Second, manufacturing firms with higher levels of production technology use ICT more effectively and achieve a higher impact on labor productivity. The results confirm that the Vietnamese government can stimulate ICT application and digital transformation in firms, thereby increasing labor productivity and promoting economic restructuring in the direction of shifting from agriculture to industry and from low-tech industries to high-tech ones. The results also provide implications for business managers and policymakers in other developing countries who are adopting the digital economy as a development strategy.

Keywords: ICT, Economic Impact, Economic Restructuring, Manufacturing, Vietnam

JEL Classification Code: O12, O14, O33, L16

1. Introduction

Over the past few decades, the world economy has witnessed strong development of information and communication technology (ICT) and digital economy. ICTs open opportunities for businesses and economies with higher productivity and new business models that have never appeared in the past (Alibekova et al., 2020). For developing countries, ICT and the digital economy are also opportunities for rapid growth, shortening the gap with developed ones (Alibekova et al., 2020).

As a developing country, Vietnam has made the digital economy a national economic development strategy. The Prime Minister on June 3 issued Decision No.749/QD-TTg approving the National Digital Transformation Programme by 2025, with orientations toward 2030. Under the scheme, Vietnam will experiment with a range of new technologies and models, strive to completely renovate the way in which the Government operates, update business operations, develop the working lifestyles of citizens, alongside creating a safe, secure, and humane digital environment (Vietnam Prime Minister, 2020). Accordingly, one of the important solutions is the application of ICT and digital transformation in the business activities of firms.

The digital economy strategy is part of a larger economic development and restructuring strategy aimed at modernizing and industrializing Vietnam. The basic idea is that productivity growth is not generated solely by productivity improvements in the production sphere, but also through the reallocation of resources out of less productive economic activities and into more productive i.e., economic restructuring process, and ICT supports these processes. The socio-economic development strategies for the period 2011–2020 and 2021–2030 have highlighted the importance of industrialization as well as the increase in the

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country's productivity and competitiveness. Specifically, out of the 7 economic goals set out in the socio-economic development strategy for the 2021–2030 period, there are three that emphasize these contents, including (1) Proportion of manufacturing industry accounts for about 30% of GDP, the digital economy is about 30% of GDP, (2) The contribution of total factor productivity (TFP) to growth is 50% and (3) The growth rate of social labor productivity is about 30%; the average of over 6.5% per year (Communist Party of Vietnam, 2021). Promoting the application of ICT and digital transformation in production, especially in industrial production, is one of the policies implemented by the government to help firms innovate products and business processes, create revenue growth, and increase labor productivity for economic restructuring and Vietnam's socio-economic development goals.

The relationship between ICT application and labor productivity has been studied by many scholars in different economic sectors and economies. Although theoretically, most studies confirm a positive relationship between ICT application and labor productivity, empirical research results are not consistent. Many studies have demonstrated the existence of a relationship between these two variables. Others failed to show a statistically significant relationship. In the case of Vietnam's manufacturing sector, a question that has arisen in the context of digital transformation and economic restructuring is whether the use of ICT increases labor productivity in the manufacturing sector, and thus supports the country's economic restructuring towards industrialization and modernization.

The objective of this paper is to clarify the relationship between ICT application and labor productivity in manufacturing firms and connect it with the context of economic restructuring in Vietnam. The article is based on the data of 3,428 manufacturing firms from the Vietnam General Statistics Office. The article is organized as follows. After the introduction, the article will review the studies done on the relationship between ICT, labor productivity in firms, and economic restructuring. Section 3 of the article presents an overview of the current state of Vietnam's manufacturing sector. Section 4 is the research model and data. Section 5 presents and discusses the results of the research before the conclusions are made in the final section.

2. Overview of Vietnam's Manufacturing Industry and ICT Application

The industrial sector consists of four main industries, namely (1) mining, (2) manufacturing, (3) electricity-gas production and distribution, and (4) water supply and drainage, in which manufacturing usually plays the leading role, creating the greatest added value for the industrial sector.

Vietnam's manufacturing industry consists of 33 sub-sectors with a total of 26,245 firms (in 2019), accounting for more than 20% of Vietnam's total number of firms. Manufacturing firms are diverse in terms of production technology level, size, and ownership. Most of Vietnam's manufacturing firms are at a low level of technology, mainly processing firms in the fields of garment, footwear, or manufacturing wood products; thus, despite the large labor force, the added value created is low (Vietnam GSO, 2020). The economic restructuring in the direction of industrialization and modernization of Vietnam in the manufacturing industry is also reflected in the shift from low-tech firms to high-tech firms.

Vietnam's manufacturing industry has made success in development and structural transformation over the past decade. Manufacturing's share of total national GDP gradually increased from 13.0% in 2010 to 16.5% in 2019. The share of the manufacturing labor force in the economy's total employment increased at a faster rate, from 13.5% in 2010 to 20.7% in 2019 (Figure 1). The proportion of the manufacturing industry in Vietnam is still low in comparison with other developing countries. In 2019, China's manufacturing sector accounted for 27.1% of GDP; the manufacturing proportion in the GDP of Thailand and Malaysia are 25.3% and 21.5%, respectively (MOIT-UNDP, 2019). It is not to mention the fact that, as a result of globalization and the international division of labor brought about by foreign investment flow, the manufacturing industry of developing countries with higher levels of development has been relocated abroad, implying that the manufacturing capacity of these countries may be much larger than reported.

The labor productivity of the manufacturing industry in Vietnam has improved over time, but the gap between it and the average labor productivity of the economy is widening. This is because the labor movement of the industry is faster than the shift in GDP. In 2019, the labor productivity of the whole economy was $4.772/worker (110 million VND/worker) while the manufacturing industry's labor productivity was only $3.809/worker (88 million VND/worker) (see Figure 2).

The increase in labor productivity in a given industry is considered to be a key factor in supporting economic restructuring and increasing the contribution of that industry to the GDP of the economy. Vietnam's socio-economic development strategy for the period of 2021–2030 sets the goal that by 2030, the proportion of manufacturing in the total national GDP should be 30%. Continuing to increase, manufacturing productivity is an important factor in achieving this restructuring goal.

Some empirical works have demonstrated the impact of ICT on the business results of manufacturing firms in many ways. ICT usage supports operational leadership presented by lower production, labor costs, value-added of products and services, and marketing efficiency (Tewari & Misra,

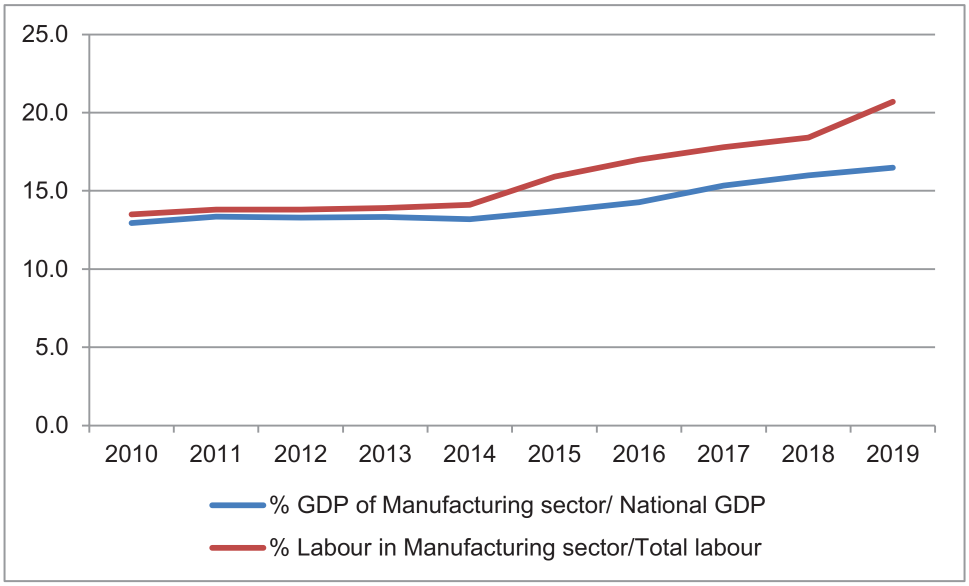

Figure 1: The Share of Manufacturing in the Economy

Source: Calculated from Data of Vietnam GSO (2020).

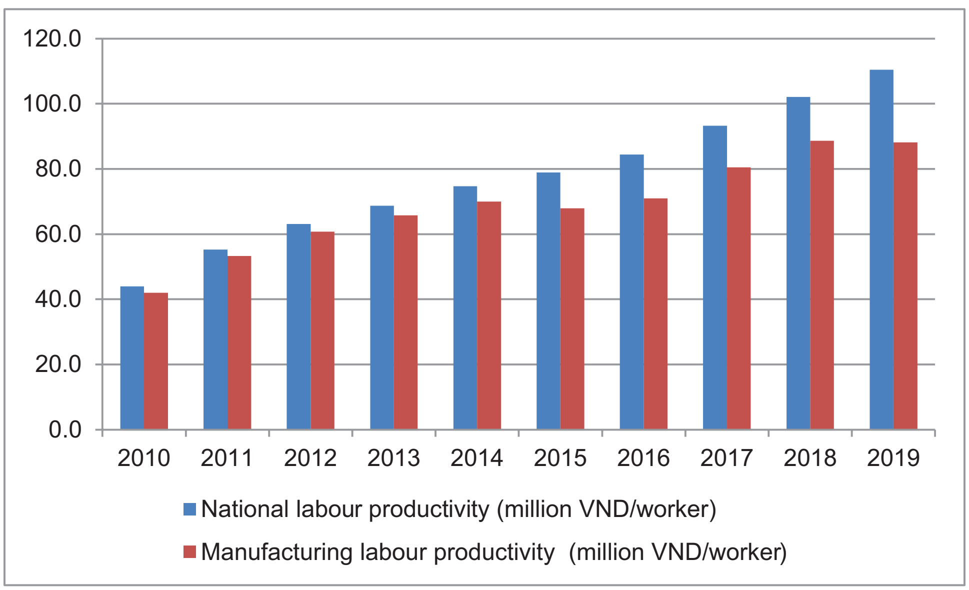

Figure 2: Manufacturing Labor Productivity compared to the Economy

Source: Calculated from Data of Vietnam GSO (2020).

2012). Investment in ICT and the use of ICT can increase many measures of performance including the increase in productivity, reduction of costs, increase in market share, increase in margin and profits, development of new products, services, and processes, improvement of product and service quality, improvement of speed of product delivery, improvement of external communication, and improvement of coordination and internal communication. Vietnamese firms have also been applying ICT for production and business. However, the level of ICT application in Vietnam's manufacturing firms has just at a basic level with general-use ICTs such as computer, internet, email, web. Most manufacturing firms do not know about the breakthrough technologies. Only 15% of manufacturing firms use cloud computing and 12% use device-to-device/product connection, less than 1% use 3D printing technology as well as ICT solutions for data analysis and management (MOIT-UNDP, 2019). Even so, the most basic ICT applications are considered to be able to improve the labor productivity of Vietnamese manufacturing firms.

3. Literature Review

3.1. ICT and Enterprise Productivity

Theoretically, there are two different arguments on the relationship between ICT application and business performance. Porter (2001) believed that ICT can help firms build and maintain competitive advantages. In particular, the view of Resource-Based View (RBV) of competitive advantage on strategic management insists that the performance of firms depends on their resources, competencies, and dynamic capabilities (Makadok, 2001). Together, these resources help businesses create rare, hard-to-copy values and thus build sustainable competitive advantages for businesses in the market. Accordingly, ICT is considered a resource that can help bring competitive advantages and sustainable benefits for businesses and improve operational results.

In contrast, Carr (2003) argued that ICT spreads and becomes popular with all firms, thus loses the meaning of business differentiation. Moreover, the application of ICT requires the costs associated with technology investment, technology transfer as well as the need for structural and organizational changes, i.e., the digitalization process, from firms. If firms cannot change, ICT investment will reduce their performance; the firms face the productivity paradox (Solow, 1987). Therefore, firms do not easily benefit from ICT investment. Firms face many challenges in using new technologies effectively in their businesses.

Empirical studies try to find solid evidence on the relationship between ICT application and business performance. The results of these studies are, however, incomplete and inconsistent.

Many quantitative studies show a positive relationship between the application of ICT and the performance of businesses. Nurmilaakso (2009) relied on a set of survey data from 1,955 EU firms to assess the impact of six common ICT solutions in e-commerce on firm performance. The results reveal that Internet access, data exchange with partners, ERP (enterprise resource planning), CRM (customer relationship management) systems contribute significantly to increasing labor productivity, while websites, SCM (supply chain management) systems do not lead to an increase in labor productivity. UNCTAD (2008) studied Thailand manufacturing firms and asserted the impact of ICT on productivity. Binuyo and Brevis-Landsberg (2014) focusing on 37 universities in Nigeria for 10 years from 2001 to 2010 and indicated the relationship between ICT investment and cost-saving efficiency. Chege et al. (2020) stated that there is a positive relationship between ICT innovation and business results of Chinese SMEs and the head of the business plays an important role in this causal relationship. Tjahjadi et al. (2020) using a sample of MSMEs (micro, small, medium enterprises) in Indonesia indicated that information capital readiness based on ICT application directly and positively affects business performance. Cataldo et al. (2020) using the regression model on the data set of 5,519 Chilean companies studied the relationship and drew three conclusions. First, the impact of ICT on firm performance depends on the stage of the application. Second, each stage of ICT application shows the positive results of ICT on revenue and profit. Third, firm size affects the impact of ICT, i.e., the smaller the company, the more positive the ICT impact on business results. Saleem (2020) used surveys and case studies to analyze and confirmed the positive relationship between ICT and organizational development, not only in terms of socio-economic development but also in terms of other developments in strategy, management, information, operations, transactions, organization, infrastructure, and transformation.

However, the application of ICT does not always lead to better business results but requires the conditions. Martin and Nguyen-Thi Thuc Uyen (2010), although affirming the enabling role of some ICT applications with innovation capacity and business performance of firms, showed the fact that investment in ICT does not necessarily lead to a corresponding increase in the enterprise's capacity to introduce new products or processes or the enterprise's overall innovation capacity. Moreover, the impact on labor productivity from product innovation only appears if businesses can sell products. Findings from Sigala (2003) revealed that productivity gains do not accrue from ICT investments per se, but rather from the full exploitation of ICT networking and informalization capabilities. Digital literacy, in particular, has been shown to have a significant impact on SMEs' performance (Sariwulan et al., 2020).

In many other cases, studies do not confirm a positive relationship between ICT applications and business performance. Chowdhury and Wolf (2013) showed that investment in ICT harms labor productivity in SMEs in three East African countries. Badescu and Garcés-Ayerbe (2009) researched 341 Spanish firms and concluded that although the firms in the sample experienced some improvements in labor productivity in the considered period, this improvement was not significantly derived from IT investment. Studies also suggest that different combinations of ICT elements in digitization also have a different impact on business results. One combination of hardware and software can be used and acts differently than another (Cho & Shaw, 2009), but few studies have shown the specific combination which can create the best impact among ICT assets (Schryen, 2013). Cataldo et al. (2020) conducted a case study of MSMEs in Chile, hypothesizing and demonstrating that businesses with a greater level of ICT asset combinations can increase key performance (revenue and profitability of MSMEs) more effectively than those with a lower level of ICT application.

3.2. ICT, Labor Productivity and Economic Restructuring

A comprehensive body of literature investigating different drivers of economic structural change points to the role of technology (Foellmi & Zweimüller, 2008; Timmer et al., 2015). Technological paradigm theory (Perez, 2004) implies that when a technological paradigm emerges there are structural changes in the economy. In the case of the ICT paradigm, the ICT manufacturing industries develop first, followed by the leading ICT using industries, and finally the remaining economic sectors. The reason for the changes is that ICT can support new business models, increase labor productivity, and the economic structure shift towards more productive sectors. As a result, there forms a new technological paradigm - a new economy associated with ICT.

Some empirical studies have been conducted to investigate the relationship between ICT, labor productivity, and economic restructuring. Copenhagen Economics (2010) concluded that there was a structural change in the EU economy based on ICT application, reallocating resources from the rest of the economy towards business services. Due to online services, the productivity of business services is relatively high, assumed to be boosted by 0.2%; this entails a GDP increase of some €5.7bn per year. Kolovou (2013) studied the case of the Finnish economy and showed that the impact of ICT on economic restructuring is mainly reflected in the effect of increasing labor productivity in ICT producing and ICT intensively using sectors, whereby the output proportion of these two industries increases over time. Zuhdi et al. (2012) showed that ICT sectors played an important role in the structural changes in Japan's economy in the period 1995–2005.

4. Research Methods

4.1. Model Specification

This study examines productivity impacts of ICT in Vietnamese manufacturing firms by running the following regression model:

$$\mathrm{lnlp}_i = \beta_0 + X_{\mathrm{ict}}\beta + Z\gamma + \varepsilon_i$$

Where lnlp_i is the logarithm of labor productivity of firm i; X_{ict} is a vector of ICT variables; Z is a vector of firm characteristics; β and γ are the associated vectors of parameters; are error terms.

lp_i is measured by value-added per employee. Previous studies have used several proxies for an enterprise's performance. Proxies are divided into three general categories, including financial, efficiency, and others. Financial ratios often used include return on investment (ROI), return on equity (ROE) (Shin, 2006), return on sales (ROS) (Tanriverdi, 2006), and aggregate revenue (Kohli & Devaraj, 2003). These proxies can often indicate an enterprise's ability to make a profit. The indicators of business efficiency to measure a firm's performance when considering the impact of ICT include labor productivity (Zhuang & Lederer, 2006), and cost of goods sold on sales (COG/S), cost of sales, and general administration cost on sales (SGA/S) (Zhu & Kraemer, 2002). Other proxies are used in certain cases, such as customer satisfaction, value-added, market share, information sharing, etc. In this study, the research model is built on the Cobb-Douglas production function. Labor productivity is used to represent the firm's performance to best match the Cobb-Douglas production function.

X_{ict} is divided into three groups of variables, including (1) variables for hardware and ICT service application, (2) variables for production and management software solutions, and (3) variables for ICT skills. The specific variables in each variable group are common ICT applications in firms (Dehning et al., 2007; UNCTAD 2008; Nurmilaakso, 2009). The ICT skill variables are added in the model since the application of ICT requires not only the technology itself but also the readiness of the human resources of firms. The majority of the ICT variables in this model are binary variables. Binary variables that distinguish between enterprises with and without access to ICT provide data for comparing differences between groups with and without access. From a theoretical point of view, however, numerical rather than binary variables are more powerful (UNCTAD, 2008).

Z includes firm characteristics such as capital intensity, number of years in operation, level of production technology, size, type of ownership, and location. These are used to eliminate the unobserved heterogeneity of the models.

In addition to the general model, the study also runs the models for sub-samples of firms of different production technology levels with the implication that firms with higher production technology will apply ICT at a higher level, and consequently have a better productivity-stimulating effect (Dehning et al., 2007). Note that most of Vietnam's manufacturing firms operate at a low technology level, mainly outsourcing firms in the field of garments, footwear, and wood products.

The regression models are estimated by using the OLS method. ANOVA tests are used to examine the effects of each factor on labor productivity. The results show that the variables under consideration all have different effects on labor productivity with a statistical significance of 5%. Bi-variate correlations statistics reveal the variables in the sub-ICT groups such as Hardware, Software, and Skills are highly correlated. This most likely leads to the problem of multicollinearity in the estimation model (high R2, but the variables are not statistically significant). Therefore, the authors run separate models for each ICT variable. Most models have omitted variables problem and heteroskedasticity (the reason may be endogeneity problem caused by omitted variables) but no perfect multicollinearity problem. The omitted variables problem and heteroskedasticity are solved by White heteroskedasticity or Robust regression.

4.2. Data

This study uses data from the Enterprise Survey (ES) conducted by the General Statistics Office of Vietnam in 2018. The survey on enterprise ICT usage was first conducted in 2018 and has not been reconducted, so there is no newer data available in the study. The list of variables using in the regression models is presented in Table 1.

Table 1: Data Description

Variables	Description
lnlp	Labor productivity (logarithm)
lnkl	Capital intensity (logarithm)
lnage	Year in operation (logarithm)
lnage^2	Year in operation (logarithm, square)
ICT	
ICT Hardware and Services	
PC	Use PCs, laptops, tablets (equal 1 if true)
internet	Use the Internet (equal 1 if true)
email	Have an email (equal 1 if true)
website	Have a website (equal 1 if true)
social_network	Use a social network (equal 1 if true)
information_sharing	Use ICT in sharing information inside the enterprise (equal 1 if true)
ICT Software Application	
MES	MES – Manufacturing Execution System(equal 1 if true)
ERP	ERP- Enterprise Resource Planning (equal 1 if true)
PLM	PLM – Product Lifecycle Management (equal 1 if true)
PDM	PDM – Product Data Management (equal 1 if true)
PPS	PPS – Production Planning System (equal 1 if true)
PDA	PDA – Production Data Acquisition (equal 1 if true)
MDC	MDC_ Manufacturing *Data* Collection (equal 1 if true)
CAD	CAD – Computer-aided Design (equal 1 if true)
SCM	SCM- Supply chain management (equal 1 if true)
ICT Skills	
skill1	Basic ICT skill (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill2	Automatic technology skill (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill3	Data analysis skill (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill4	Information security skill (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill5	The skill of developing and application ICT support systems (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill6	Collaboration software skill (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
skill7	Non-tech skills such as system logic and system knowledge (1–4, equal 1 if do not meet requirements, equal 4 if well fit requirements)
Control variables: Production Technology, Size, Ownership, Location	

For the control variables, the study uses conventional classifications. Enterprise sizes are divided into small, medium, and large firms according to the number of employees (Government of Vietnam, 2018); types of ownership are divided into state-owned firms (SOE), domestic private firms (DPE), and foreign investment firms (FIE); location includes 6 economic regions according to Vietnamese classification. For the level of production technology, the study uses the same classification of firms by technology level as in the study of MOIT-UNDP (2019). Accordingly, high-tech manufacturing firms include those producing chemicals, drugs, electronic products, electrical equipment, motor vehicles, and means of transport. Medium-tech firms include those producing coke, refined petroleum products, products from rubber and plastic, metal, prefabricated metal products, other non-metallic mineral products, repair, maintenance, and installation of machinery and equipment. Low-tech firms comprise those producing food, beverage, tobacco, weaving, costumes, leather, products from wood, bamboo, and cork, paper, print product, copy records, furniture, and other processing and manufacturing industries.

After a data mining process, the total sample includes 3,428 firms. Table 2 presents the summary statistics, listing the number of observations, mean, standard deviation, minimum and maximum of the full sample. The results show that most of Vietnam's ICT manufacturing firms have basic ICT applications such as PC, Internet, and email. Specifically, the proportion of firms using PC, Internet, and email is 96%, 95%, and 96% respectively. When it comes to more recent applications such as having a website, using social networks, and applying ICT for information sharing in the enterprise, the usage rate drops significantly. Only 22% of the firms have websites, 32% use social networks, and 20% use ICT systems for information sharing.

Table 2: Data Summary

Variables	Min	Mean	cv	Max
lnlp	−1.1	5.77	0.26	10.7
lnkl	−2.38	6.1	0.22	11.31
lnage	0	7.94	0.84	67
PC	0	0.96	0.21	1
internet	0	0.95	0.23	1
email	0	0.96	0.22	1
website	0	0.22	1.9	1
social_network	0	0.32	1.45	1
information_sharing	0	0.20	1.98	1
MES	0	0.07	3.55	1
ERP	0	0.08	3.33	1
PLM	0	0.05	4.37	1
PDM	0	0.12	2.73	1
PPS	0	0.10	3.06	1
PDA	0	0.10	3.03	1
MDC	0	0.06	3.89	1
CAD	0	0.09	3.22	1
SCM	0	0.05	4.37	1
skill1	1	2.13	0.48	4
skill2	1	1.82	0.52	4
skill3	1	1.79	0.54	4
skill4	1	1.94	0.52	4
skill5	1	1.73	0.54	4
skill6	1	1.78	0.54	4
skill7	1	1.69	0.55	4

The percentage of firms that apply specialized software solutions for production and management support is very low. The software solutions which are more popular include PDM (Product Data Management), PPS (Production Planning System), and PDA (Production Data Acquisition) with the applying percentage is from 10% to 12% only. Regarding ICT skills, the survey gives an assessment on a 4-level scale, whereby the assessment of most skills is just above or below 2, that is, at a weak level, not meeting the requirements of firms.

From the comparative statistics of the main variables in the equation for 3 groups of firms with high, medium, and low production technology, it is noted that the level of ICT application (for all hardware, services, and software) is in line with the production technology level of the firms. High-tech firms apply ICT more; low-tech firms use ICT less. The ICT skill level of employees of high-tech firms is also higher and it decreases with the technology level of firms. Thus, in addition to a higher level of ICT application, high-tech manufacturing companies also exhibit a better combination of ICT applications. Cho and Shaw (2009) and Cataldo et al. (2020) considered ICT combination a condition to effectively promote labor productivity when applying ICT in enterprises.

5. Results

The results of the overall model on the relationship between ICT and labor productivity of Vietnamese firms are shown in Tables 3, 4, and 5. Overall, the models have a good fit. The estimated parameter accurately reflects the prediction based on the theory. Capital has a positive effect on labor productivity. Meanwhile, the relationship between the number of years of operation and the productivity is of inverted-U shape, that is, the labor productivity of the enterprise increases as the number of years of operation increases due to the scale expansion, cost savings, and better business management experience. However, as firms continue to operate, inertia without suitable reorganization can reduce labor productivity.

The results in Table 3 shows that basic ICT hardware and service applications have a positive impact on enterprise productivity. Firms using PCs have 44.38% higher labor productivity than firms without PCs. The corresponding numbers for Internet, email and website are 39.46%, 39.01%, and 31.98%, respectively, which are all remarkably high. Even with lower-impact applications such as social networks or the use of ICT for information sharing, the productivity gap between businesses with apps and those without apps is significant. All ICT variables have an impact on labor productivity at a 1% significance level. Similar results were obtained by Atrostic and Nguyen (2005) in the case of the United States, and UNCTAD (2008) in the case of Thailand and Nurmilaakso (2009) in the case of the EU. For example, UNCTAD (2008) studied the manufacturing industry of Thailand and the results showed that firms with a computer, Internet and web applications have higher labor productivity by 15.59%,

Table 3: Impact of ICT Hardware and Services on Manufacturing Labor Productivity

Variables	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp
lnkl	0.5837***	0.5833***	0.5838***	0.5742***	0.5877***	0.5825***
lnage	0.1933**	0.1919**	0.1911**	0.2111***	0.1992***	0.196**
lnage^2	−0.02116	−0.01955	−0.01917	−0.0313	−0.02241	−0.0217
PC	0.4438***					
internet		0.3946***				
email			0.3901***			
website				0.3198***		
social_network					0.1116***	
information_sharing						0.2433***
cons	2.172***	2.2***	2.201***	2.512***	2.482***	2.457***
Obs	3428	3428	3428	3428	3428	3428
F	139.11	137.00	136.95	150.08	137.76	144.32
R^2	0.41	0.41	0.41	0.41	0.40	0.41
Control variables: Production technology, Size, Ownership, Region						

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

Table 4: Impact of ICT Software Application on Manufacturing Labor Productivity

Variable	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp
lnkl	0.5871***	0.586***	0.5866***	0.5854***	0.5862***	0.5857***	0.5874***	0.5893***	0.5876***
lnage	0.1946**	0.1991***	0.2033***	0.1967***	0.1975***	0.1935**	0.1986***	0.2015***	0.1964**
$lnage^2$	−0.02113	−0.0228	−0.02377	−0.02167	−0.0225	−0.02094	−0.02215	−0.02422	−0.02253
MES	0.2627***								
ERP		0.2176***							
PLM			0.3664***						
PDM				0.2861***					
PPS					0.3106***				
PDA						0.2852***			
MDC							0.2939***		
CAD								0.2816***	
SCM									0.2861***
Cons	2.468***	2.456***	2.461***	2.461***	2.453***	2.465***	2.467***	2.454***	2.485***
Obs	3428	3428	3428	3428	3428	3428	3428	3428	3428
F	141.30	140.40	141.74	142.96	143.17	141.88	140.46	141.23	140.60
R^2	0.41	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.40
Control variables: Production technology. Size. Ownership. Region									

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

Table 5: Impact of Employee's ICT Skills on Manufacturing Labor Productivity

Variable	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp	lnlp
lnkl	0.5847***	0.5824***	0.5823***	0.5818***	0.5842***	0.5821***	0.5824***
lnage	0.1963**	0.1944**	0.1965**	0.1947**	0.1968**	0.1922**	0.1892**
lnage^2	−0.02273	−0.02185	−0.02227	−0.02227	−0.02228	−0.02114	−0.01981
skill1	0.09467***						
skill2		0.1060***					
skill3			0.1314***				
skill4				0.1279***			
skill5					0.1116***		
skill6						0.1169***	
skill7							0.1226***
Cons	2.312***	2.324***	2.267***	2.26***	2.31***	2.308***	2.306***
Obs	3428	3428	3428	3428	3428	3428	3428
F	139.67	144.28	145.60	144.41	142.86	142.22	145.72
R^2	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Control variables: Production technology. Size. Ownership. Region							

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

3.22%, and 4.18% than firms without these applications, respectively. Similarly, Nurmilaakso (2009) found that businesses using the Internet and websites can create higher labor productivity than firms without these applications by 42.7% and 6.3%, respectively. The impact coefficients in the case of Vietnamese manufacturing firms are generally higher than the corresponding data found in Thailand and EU firms. This is consistent with the tested hypothesis of Cataldo and McQueen (2014) that simple ICTs are more significant in countries of a lower level of development than those of a higher level of development.

The productivity impact of ICT software applications in Vietnamese manufacturing firms is generally lower than that of basic ICT hardware and services and is comparable among different software solutions. Two higher impact software solutions are PLM (Product Lifecycle Management) and PPS (Production Planning System). These are also the solutions that are most commonly applied in Vietnamese manufacturing firms. Firms that apply these software solutions have higher labor productivity than those which do not by 36.64% and 31.06%, respectively. Cantamessa et al. (2012) investigated an aerospace company and concluded that PLM favored a tighter workflow logic, easier product carryover, and more efficient product data retrieval, thereafter boosted the firm's productivity.

All ICT skills also have a positive impact on the productivity of firms. The level of impact is generally lower compared to that of hardware and software. Data analysis skills (skill 3) and Information security skills (skill 4) are the two most important. Firms having employees with these two skills at a better level can create 13.14% and 12.79% higher labor productivity, respectively, than firms where these two employees' skills do not meet or respond weakly to business requirements.

Table 6 presents the results of the comparison model between sub-samples of firms with different levels of production technology. Most of Vietnam's manufacturing firms are low-tech (accounting for 51.60% total number of firms in the sample). The number of firms with medium technology level accounts for 28.47% and the number of firms with high technology level accounts for only 19.93%.

It is shown that most of the ICT hardware and service variables are statistically significant in the sub-sample models. Comparing the magnitudes of the estimated parameters in the three groups of firms, it can be seen that firms with a higher level of production technology can better exploit the productivity-enhancing effects of ICT hardware applications and services. For example, a website application can increase the labor productivity of a high-tech enterprise by 44.35%. This impact on the group of firms with medium and low technology levels is 33.51% and 24.82%, respectively.

Similar comparison results are also found in the models of the relationship between software applications and labor productivity. Firms with a higher production technology level use ICT more effectively. For example, firms applying PDM (Product Data Management) have 37.72% higher labor productivity than firms not applying this software in the group of high-tech firms. The data for two groups of firms with medium and low technology levels are 25.77% and 18.84%, respectively. All 9 software solutions have a statistically significant positive impact on labor productivity for both high- and medium-tech firms. In the low-tech group, however, there were 3 software solutions not statistically significant, including MES (Manufacturing Execution System), EPR (Enterprise Resource Planning), and MDC (Manufacturing Data Collection).

For the models running with ICT skills, the comparison results are slightly different. Though the impact of ICT skills on labor productivity is best in the group of high-tech firms, the second-highest impact level is for low-tech firms and the last place is for medium-tech firms. This is true for 6/7 skills, from skill 2 to skill 7.

These results are in agreement with the results of Dehning et al. (2007), according to which high-tech manufacturing firms that adopt ICT-based systems will enjoy greater financial performance improvement than non-high-tech manufacturing firms. This can be explained in a number of different ways. First, in high-tech companies with short production cycles, ICT is used to enable the flexibility demanded by the short production cycle. Second, high-tech enterprises are more likely to face unpredictable demand due to the innovative product's fundamental characteristics, as well as the consequences of obsolescence or shortages for an early sales leader, and ICT applications help firms to react flexibly with the unpredictable challenges. Third, the dynamic production organization characteristics of high-tech products can be suitable for ICT adoption, so high-tech firms can be easier to adapt to gain the benefit of ICT. Fourth, the high-skilled workforce in high-tech firms can better grasp ICT skills which in turn push labor productivity. Furthermore, a more uniform combination and integration of ICT application aspects in high-tech manufacturing firms can lead to better productivity gains.

6. Conclusion

The study uses data of 3,428 manufacturing firms from the General Statistics Office of Vietnam and a regression model to examine the relationship between ICT and labor productivity in manufacturing firms in general in Vietnam as well as compare this relationship in the case of firms with different levels of production technology.

Research results show two main points. First, information technology can boost the labor productivity of Vietnamese manufacturing firms. This is true for both hardware applications, ICT services, ICT software solutions, and employees' ICT skills in firms. Among ICT applications, the

Table 6: Comparative Impacts of ICT on Firms' Labor Productivity according to Production Technology Levels

Variables	High-Tech Manufacturing Firms	Medium-Tech Manufacturing Firms	Low-Tech Manufacturing Firms
	lnlp	lnlp	lnlp
ICT Hardware and Services			
PC	0.7275***	0.4738	0.3477**
internet	0.3852*	0.5292**	0.3807***
email	0.4401*	0.5367**	0.352**
website	0.4435***	0.3351***	0.2482***
social_network	0.2590**	0.1411*	0.0620
Information_sharing	0.3070***	0.1752**	0.1979***
ICT Software Application			
MES	0.3968***	0.2786***	0.1439
ERP	0.3618***	0.2737**	0.0640
PLM	0.2914**	0.3569**	0.2856**
PDM	0.3772***	0.2577***	0.1884**
PPS	0.2252**	0.3174***	0.2735***
PDA	0.3491**	0.2527**	0.2364***
MDC	0.3497***	0.3100**	0.163
CAD	0.4703***	0.2333**	0.1553*
SCM	0.3323*	0.3322***	0.1847
ICT Skills			
skill1	0.0918*	0.1129***	0.0792***
skill2	0.1568***	0.0815**	0.0868***
skill3	0.1899***	0.1091***	0.1100***
skill4	0.1738***	0.0994***	0.1161***
skill5	0.1647***	0.0717**	0.0941***
skill6	0.1601***	0.0820**	0.1097***
skill7	0.1589***	0.0795**	0.1201***
N	683	976	1769

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

impact of ICT hardware and services is the highest, which is followed by the impact of software solutions and employees' ICT skills. Second, manufacturing firms with a higher production technology level apply ICT at a higher level and achieve a higher impact on labor productivity.

These two results which are set in the context of Vietnam have connected two economic strategies, including the building digital economy and the economic restructuring towards industrialization and modernization. The findings show that the Vietnamese government should encourage ICT adoption and digital transformation in businesses, boosting labor productivity and supporting economic restructuring toward a transition from agricultural to industry and from low- to high-level industries.

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