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ABSTRACT

This study disentangles the relationship between GVC participation and the technical efficiency of SMEs in Vietnam. We combine panel data obtained from the GSO Enterprise Census survey of SMEs in Vietnam including 567,866 enterprises observations from 2015 to 2018. Regarding global value chain participation (GVC), TiVA databases by OECD are used to track GVC integration at sectoral level. We employ Stochastic frontier analysis (SFA) to gauge the relationship between a firm's technical efficiency and GVC participation in two modes of participation: backward integration and forward integration. The findings show the positive impacts of backward participation in rising technical efficiency levels. However, SMEs in sectors with deeper forward participation tend to have low technical efficiency. We find the heterogeneity in firm efficiency regarding firm-specific factors and location.

Keywords: GVC participation, SMEs, Technical efficiency.

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1. Introduction

Over the last two decades, the industry has become the main engine for Viet Nam's rapid growth. In 2016, it accounted for 55% of the total workforce and 62% of national value-added, both of which are significantly higher than the corresponding OECD averages (23% and 33%, respectively) (OECD, 2021).

In Vietnam, small and medium enterprises (SMEs) is defined as *"enterprises with either fewer than 300 workers or have registered capital of less than VND 10 billion*. By the end of 2020, SMEs will constitute 97,3% of the total 684.260 official enterprises. The expansion of SMEs over the years has also been an essential feature of the rapid economic growth and sustainable development in Vietnam (Prasanna et al., 2019). However, in the context of globalization, SMEs in Vietnam have been facing many challenges in the future. Many small firms continue to operate as household businesses at the boundary between formal and informal. They frequently maintain credit lines and/or restrictions, with negative effects on the optimal allocation of scarce resources, and productivity. Especially in international markets, the issue of governance capacity and access to new-generation technology are also the top concerns for Vietnamese SMEs that are preventing them from enhancing their performance in terms of productivity (labour productivity, TFP) and technical efficiency (Mwika et al., 2018; Nguyen, 2019).

Technical efficiency refers to the ability of firms to maximize output with a specific number of given inputs, or the ratio of its mean output to the corresponding mean output if the firm utilized all its resources (inputs) efficiently. Kumbhakar et al. (2000) first introduced this term and maintained that technical efficiency is the firms' ability to produce to get the maximum output from a set of input (output-oriented approach) or to produce output using the lowest amount of input (input-oriented approach). In other words, technical efficiency is governed by the relationship between technology used and potential production or how close a firm is to the production frontier of its related technology (Aparicio et al., 2023). In vietnam, numberous studies have investigated the determinants of firm technical efficiency, such as: firm size, firm age, capital intensity, etc. Few studies have tacked technical efficiency with trade openness or intergration as Vietnam participate more in the international market. Moreover, in recent years, the rapid development of global value chains (GVC) has emerged as unprecedented new features in international trade. That has sparked new concerns about the impact of GVC participation on firm technical efficiency.

The nature of international trade has changed as final goods are no longer the main trading article, but rather intermediate goods. Baldwin & Venables (2013) defines GVC as the series of stages in the production of a product or service for sale to consumers in which Each stage adds value, and at least two stages are in different countries. According to this definition, a firm participates in a GVC if it produces at least one stage in a GVC. Those stages include activities such as research and development (R&D), design, production, marketing, distribution and support to the final consumer. In our study, we mention two components of GVC participation, backward and forward linkages (Epede & Wang, 2022). GVC participation is beyond the traditional definition of international trade, not only direct export or import but also including the supply of inputs for global production network. For developing countries, SME involvement in the GVC could be either through trading activities or engaging with lead or multinational firms (Kuzmisin et al., 2017; Tajoli & Felice, 2018). This participation allows SMEs to leverage their comparative advantage in a specific task, access more market with low-price input. In addition, it can attract more foreign direct investment (FDI) which help SMEs in developing countries take advantage of superior technology transfers from foreign partners, indirectly participating in GVC without paying high entry costs to foreign markets, which is also the most common way to link developing countries with GVCs (Amendolagine et al., 2019; Hattari et al., 2014; Taglioni & Winkler, 2016).

Generally, resource endowment, efficiency maximization, market access are three key growth drivers for GVC (ADB, 2021). The primary goal of efficiency maximization is to reduce costs within an enterprise or the overall supply chain in order to achieve high productivity (Christopher, 2011). Supply chain management concepts such as zero inventory, just-in-time delivery of goods, and outsourcing have both been designed to reduce total supply chain costs. Consolidated operations (e.g., supplier or logistics consolidation) and production agglomeration (e.g., industrial or SME clusters) can also reduce total supply chain costs by achieving low transaction costs and economies of scale. Hence, assessing the efficiency level of SMEs in the context of GVC would be beneficial to paving the way for upgrading in the global value chain. With the discrepancy of research related to technical efficiency and firms in GVC, our study aims to fill in this gap. We examine determinants of technical efficiency of SMEs in Vietnam with the context of GVCs development by using the Stochastic Frontier Approach (SFA) to clearly investigate the link between GVCs participation and the firm's performance, i.e., technical efficiency. Our results can act as a source of reference for policymakers to enhance domestic firms' technical efficiency and performance in general, providing more advice that helps SMEs insert in GVCs and gain more benefit from it.

2. Literature review

2.1. Determinants of firm technical efficiency

Factors affecting the technical efficiency of firms can be classified into two stands – internal factors related to firm characteristics and external factors related to the business environment.

Firm size

Charoenrat et al. (2013) analyze factors affecting the technical efficiency of small-and-medium enterprises in the Thai manufacturing industry, adopting the SFA method suggested by Battese & Coelli (1995). The study suggests that firm size is the most important determinant of technical efficiency since large firms can acquire new technology better than small firms, thanks to capital abundance. Following the parametric approach suggested by Cuesta (2000), Kim et al. (2012) empirically examine TFP changes, technical efficiency change (TEC), and technical progress (TP) for factory groups in the Malaysian manufacturing industry from 2000 to 2004. The result shows that firm size significantly affects TFP, TEC and TP, in which large factories are more likely to exhibit higher technical efficiency change and technical progress. This finding aligns with previous studies of Assefa Admassie & Matambalya (2002), Lundvall & Battese (2000), and Le & Harvie (2010). Applying DEA, Bhandari & Ray (2012) figure out the positive relationship between firm size and technical efficiency.

However, the effect of firm size on technical efficiency is mixed, and some studies point out the negative relationship between firm size and technical efficiency. Cheruiyot (2017), using cross-sectional data from 396 firms in the Kenyan manufacturing sector in 2007, analyses technical efficiency determinants with the SFA method. The positive coefficient of firm size in the regression equation regarding technical inefficiency is explained as large firms have complicated organizational structures, causing the decision-making process to be time-consuming and rigid. Margono & Sharma (2006) investigate TFP changes and technical efficiency changes in various manufacturing industries in Indonesia from 1993 to 2000, suggesting that firm size and technical efficiency are negatively related.

Firm age

Similar to firm size, the magnitude of effect of firm age on technical efficiency is indeterminable, depending on the time period and geographical location. Studies by Assefa Admassie & Matambalya (2002); Wadud (2007), Walheer & He (2020) all point out the positive relationship between firm age and technical efficiency. Charoenrat et al. (2013) explain that firms with the early establishment are more experienced in utilizing resources. They learn from the past via the "learning-by-doing" mechanism and improved management ability. Especially in the textile industry, research by De Jorge-Moreno & Rojas Carrasco (2015) suggests that firm age is significant in improving the technical efficiency of textile companies since older firms have greater market knowledge and reputation and enjoy larger benefits from economies of scale. Similarly, Wadud (2007) explains that larger Australian textile companies have achieved greater technical efficiency through a more efficient division of labour rooted in learning by doing, management experience and skills.

The negative effect of firm age on technical efficiency was investigated in several studies. Particularly, Charoenrat & Harvie (2014) suggest that firm age does not sufficiently guarantee the technical efficiency improvement of SMEs in the Thai manufacturing industry. In the automobile industry of India, young domestic firms exhibit higher technical efficiency than old domestic firms due to young firms being more susceptible to new technology. They are more likely to adopt new technology effectively (Sur & Nandy, 2018). Cheruiyot (2017) provides the additional argument that some old firms tend to be stuck into relatively old physical capital. In other words, old firms are less likely to make old equipment redundant to upgrade new technology. Such classical physical capital may be lower than the industry average, causing the efficiency decline with firm age, similar to Yasin & Sari (2022). Wang & Wong (2016) analyze data from 12,395 firms in the manufacturing industry in 2015, finding that old firms show lower levels of technical efficiency. Firm age increases by one year, making technical efficiency drop by 1.4%.

Capital intensity

Wadud (2007) investigates the technical efficiency of firms in the textile industry in Australia show that capital intensity has a negative effect on technical efficiency. De Jorge-Moreno & Rojas Carrasco (2015) find evidence of the negative relationship between capital intensity and technical efficiency. A plausible explanation is that technical efficiency depends on the nature and popularity of technology. If the firm can easily incorporate such technology, it can indeed increase technical efficiency. If the technology requires a substantial investment or organizational changes, it can cause a shift in frontier, which then make a change in the relative distance to the optimal level. It means increasing capital intensity can improve the technical efficiency in the future but can negatively affect the short-run technical efficiency. However, capital intensity is found to significantly affect the firm efficiency. For example, Rath (2018) suggests that capital intensity is positively associated with TFP changes in manufacturing, textile and IT in India.

Quality of labour force

Labour is one of the most crucial factors of production. In the first stage, the production function takes into account the effect of labour in determining output. Many studies zoom into the effect of the quality of human capital on technical efficiency in the second stage. Söderbom & Teal (2004) examine reasons for the technical inefficiency of manufacturing firms in Ghana. Using panel data of 143 firms from 1991 to 1997 to estimate with SFA, authors show that differences in human capital, including skills, education, etc., can be responsible for technical efficiency differences. Chaffai et al. (2012) analyze factors affecting the technical efficiency of textile firms in 8 countries: Brazil, Ecuador, Egypt, India, Maroc, Pakistan, and South Africa. The result suggests that the management experience and education level of the labour force improves the labour productivity and technical efficiency of firms. Charoenrat and Harvie (2014) use the share of skilled labour as a proxy for human capital, finding that the share of skilled labour significantly determines the technical efficiency of SMEs in manufacturing in Thailand. The positive impact of human capital on technical efficiency is analyzed in studies of Cheruiyot (2017) and Kashiwagi & Iwasaki (2020) using the same proxy. Yang et al. (2010) suggest that on-job training positively contributes to TFP changes. Firm's expenditure on health insurance and pension for employees as parts of compensation can raise labour productivity. Naz et al. (2017) employ a non-parametric approach with the Malmquist index and conclude that the root cause of low productivity in the textile industry of Pakistan is the lack of skilled labour.

Raw inputs/materials

Some studies centre on the effect of imported materials on a firm's technical efficiency. Dwivedi (2012) examines TFP change, and technical efficiency change in the electronics industry of India in 2 periods: 2000 – 2001 and 2009 – 2010. The finding suggests that importing raw materials generates a positive impact on the technical efficiency and productivity of firms in the industry. Zhu (2023) analyses the effect of participating in the global value chain on the technical efficiency of manufacturing firms in China. The result confirms findings from previous studies, in which imported materials have better quality and more reasonable prices, hence increasing the exploitation of efficiency. Evidence to support counterarguments is relatively limited. For instance, Yasin & Sari (2022a) point out that importing raw materials reduces technical efficiency.

Firm ownership

The large body of literature discusses the differences in technical efficiency between private firms and FDU firms. Most scholars agree on the magnitude of effect, in which FDI firms tend to have higher technical efficiency compared to domestic firms (Choi et al., 2017; Khalifah, 2013; Mastromarco & Ghosh, 2009; Otsuka & Natsuda, 2016; Sari et al., 2016; Sheu & Yang, 2005; Suyanto et al., 2014; Yang et al., 2010; Yasin & Sari, 2022b; Zhang, 2017). This result is quite consistent with the long-held view that foreign ownership is a vehicle for the international transfer of managerial skills, technical know-how and market information that cannot be licensed or transferred to customers through technical support agreements. Walheer & He (2020) argue that firm ownership is a significant determinant that explains the substantial difference in technical efficiency of manufacturing firms in China. Comparing technical efficiency between private enterprises and state-owned enterprises (SOE), private enterprises still exhibit higher levels of technical efficiency and TFP (Bhandari & Ray, 2012; Charoenrat et al., 2013; Wu & Zhou, 2013). Charoenrat et al. (2013) point out that SOEs in manufacturing have a higher level of technical inefficiency than private and FDI firms in Thailand. Yang et al. (2010) suggest SOE firms have limited ability to utilize R&D to increase productivity and efficiency in comparison to private and FDI firms. Walheer & He (2020), using data for manufacturing firms in two separate years, 1999 and 2007, shows that FDI enterprises are those with the most advanced technology and state-owned and collective firms with the least technological advancement. The technological advantage of foreign ownership is evident in many areas, and this advantage is stable over time.

Regarding business environmental factors, many studies demonstrate the important role of location in determining the technical efficiency of firms.

Location

Many studies show that companies located in municipal areas and the industrial zone will have higher levels of technical efficiency. One plausible explanation is that these firms have access to higher-quality infrastructure such as the Internet, raw material supply, and transportation services. Yang et al. (2010) indicate that manufacturing enterprises in the Beijing and Yangtze River Delta regions have higher technical efficiency due to the advantage of industrial clusters. Charoenrat et al. (2013) analyze the impact of geographical location on the labour productivity of manufacturing enterprises, showing that companies concentrated in urban areas are found to have higher productivity thanks to the ease of hiring skilled labour. Supply chain operations also have a significant impact on a business's technical efficiency. El-Atroush & Montes-Rojas (2011) assess the impact of supply chain operations on firm efficiency in India, indicating that building an efficient supply chain contributes to increased labour productivity.

In general, firm efficiency is determined mostly by firm size, firm age, quality of labour force, capital intensity, spillover of FDI upstream and downstream, and location. There is not a universal agreement on the magnitude of each variable on technical efficiency, depending largely on the location of firms and the historical development of the country. Firm characteristics are still of central interest when analyzing aspects of firm performance in combination with other new variables.

2.2. GVC participation and technical efficiency

The rise of global value chains in the past three decades has received significant attention from many researchers and policymakers (Amador, 2015; Gereffi, 1994; UNCTAD, 2017). Several aspects of this phenomenon have been investigated by economic literature, and early studies concentrate on the measurement of GVCs at broad level that the unit of analysis is a country or a country-industry. This measurement leads to the development of world input-output tables, a key tool for economists studying GVCs (Johnson, 2018; Koopman et al., 2014). This tool gives a broad view of GVC participation and positioning within GVCs, as well as the consequence of GVC participation. Generally, GVCs allow countries to benefit from the comparative advantage of other countries with product fragmentation and specialization (Antràs, 2020; Baldwin & Venables, 2013).

Recent literature on the effect of GVC participation by using firm data or sector-firm data has shed light on the link between GVC involvement and firm performance. Particularly, firm performance has taken a prominent place as a research focus on this linkage. Firm performance can be examined by various aspects such as growth, profitability, financial, innovation, productivity and efficiency (Lu et al., 2018; Mahy et al., 2018; Manello et al., 2016; Reddy & Sasidharan, 2021). Such a focus makes it clear that participation in GVCs affects firm performance through efficiency and productivity gains. A relevant strand of the extant literature focused on labour productivity, or total factor productivity (TFP) indicator representing firm productivity (Gueye et al., 2020; Manello et al., 2016; Montalbano et al., 2018; Urata & Baek, 2022a). Using firm-level data, many studies explore how GVC integration can improve firm performance in terms of productivity (labour productivity, TFP), export propensity, and profit.

Two modes of GVC participation, i.e., backward linkage and forward linkage, have implications for firm efficiency. On the one hand, backward linkage increases a firm’s efficiency through productive aspects. It allows firms to access more international markets with low-cost and high technological content intermediate input. Firms may offshore less-rewarding stages of production and focus on high-value stages, or so-called vertical specialization (Hummels et al., 1998). On the other hand, forward linkages improve efficiency, driven by the relationship between lead firm and other suppliers (i.e., firms sell intermediate goods to other companies rather than to end customers) in the chain. Conceptual studies have identified knowledge diffusion and transfer as important aspect of this link (Ernst & Kim, 2002; Inkpen & Tsang, 2005). It provides a valuable opportunity to increase SME's productivity and efficiency through learning about technologies, organizational and managerial practices (Alessandro et al., 2015). This relationship is more important with the development of relational GVCs in which businesses have to make constant exchanges with each other, requiring their activeness in keeping their reputation with business partners, thereby improving their productivity and efficiency. Stronger relationships along GVCs can reduce the cost of risk, making businesses operate more efficiently.

We review both the studies focusing productivity and studies focusing pure technical efficiency with purposes provides a clear brief review of empirical studies regarding the effects of GVC participation on firm's efficency.

Urata and Beak (2022) examine the impact of a firm's GVC participation on total factor productivity using the Basic Survey of Japanese Business Structure and Activities, Ministry of Economy, Trade and Industry, covering manufacturing firms for 1994–2018. They defined GVC participation as when a firm engaged in both importing and exporting, and found that a firm's GVC participation has generally positive impact on productivity, but not very strong. Authors point out the long-term learning effect, indicating that GVC participating firms take time to learn new technology. Del Prete et al. (2017) investigate whether only the most productive firms can join GVC and improve country's competitiveness or whether joining GVC can itself make firms more productive. Using World Bank Enterprise Surveys data for two North African countries, Egypt, and Morocco, in 2004 and 2007, the result suggests that firms which enter GVCs perform better ex-ante, and benefit from ex-post additional increases in productivity.

Thanks to the availability of new data for trade in value added, an increasing number of empirical works have addressed firms' GVC participation by value-added data (Taglioni & Winkler, 2016). Montalbano et al. (2018) use GVC participation index measuring by OECD-WTO TiVA database and match it with the last wave of the WBES firm-level data for Latin American countries (dataset with 12,146 firms distributed across 30 LAC countries). Their study shows that both participation in GVCs and position within GVCs have positive impact on firm productivity. Lu et al. (2016) use data from a large Chinese firm-level dataset with 208,078 firm-year observations for the period from 2000 to 2006 to investigate the relationship with the case of China firm and found an inverted U-shaped non-linear relationship between GVC participation and the productivity of Chinese firms. It means GVC participation will improve Chinese firms' TFP, but when the firm is over-embedded into GVCs, it will reduce TFP. Gueye et al. (2020) apply the GVC participation measure proposed by Koopman et al. (2014), which captures all sources of value added in gross exports. The research uses Estonian firm-level data from the ORBIS database, containing more than 103,000 firms in 19 NACE (General Industrial Classification of Economic Activities within the European Community) sectors from 1999 to 2016. It also proves a link between firm involvement in GVCs and productivity gains through backward and forward linkages. However, the recent study by Abdullah (2022) about Turkish firm indicates that while forward GVC participation is not significantly associated with productivity growth, simple (complex) forward participation leads to higher (lower) productivity growth.

With efficiency respective, best of our knowledge, Kamau (2009) was the first to indicate the impact of insertion in GVCs on technical efficiency in kenyan garment firms, a close constituent of process upgrading. This study's findings seem to suggest that firms that operate mainly in GVCs experience process and product upgrading and that none of the firms in this chain has managed to upgrade functionally. They also found that firms inserted in different value chains experience different levels of upgrading and, subsequently efficiency levels. Manello et al. (2016) also find the positive impact of participation in GVCs on firms' efficiency through vertical structure, an important factor influencing the technical efficiency of firms by focusing on core activities, for which their ability should be higher. However, both Kamau and Manello's studies mainly investigate on a sectoral level, and the results provide with the low level of generalization. With development from those two studies, the typical literature was conducted by Agostino et al. (2020), showed a new way to understand the relationship between firm' efficiency and GVC participation especially SMEs. The study uses a large set of Italian industrial SMEs of the MET database on Italian firms from 2008 to 2012, the GVC participation is identificated by firms' internationalization attitude (import and export activities), the type of good exported (semi- finished or final) and the share of sales to order to other companies. Meanwhile, firms' efficiency represented by pure technical efficiency indicator, retrieving DEA efficiency scores. The author found that participation in GVCs has positive impacts on SMEs' technical efficiency; benefits are greater for suppliers than final firms and larger in the case of relational than conventional participation.

Thanks to strong GVC involvement, Vietnam has emerged as one of Asian's main manufacturing powerhouse (Amendolagine et al., 2019; Hollweg, 2017). There is a huge amount of literature on the relationship between firms involved in GVCs, and their productivity in Vietnam, mainly focusing on SMEs as small firms play a significant role in economic development (Atkin et al., 2017). Some studies find that the association of GVCs have a positive impact on labour productivity. With SMEs, GVC participation may increase wages and employment (Anh, 2019; Gueye et al., 2020; Jangam & Rath, 2020; Yamashita & Doan, 2022). Moreover, Nguyen et al. (2020) have addressed the critical factors for participating and upgrading small and medium-sized enterprises in the GVC in the case of Vietnam. With the same respect, Dang & Dang (2020) estimate the effect of the Vietnamese economy's linking to global value chains on the innovation of SMEs in the manufacturing sector in Viet Nam. They define a firm's GVC participation by foreign value added in gross exports and find that GVC participation correlates negatively with SMEs' decision to introduce new products but is positively associated with their decision to improve existing products. With study conducted by Urata & Baek (2022b), investigate the effect of GVC participation on productivity in the case of 3 developing Asian country are, Indonesia, the Philippines and Vietnam. The study points out the positive impact of GVC insertion on SMEs' TFP. However, the learning effect is not clearly with SMEs in Vietnam. The main reason is the lack of data and small sample to investigate.

As the author realizes, very few studies have tacked these topics through technical efficiency in Vietnam. Although not explicitly analyzing the effect of GVC participation on firm's efficiency, few studies have examined the effects of exporting and importing on a firm technical efficiency. Hung et al. (2010) provide empirical evidence of a positive relationship between export orientation, trade openness and technical efficiency in Vietnam by using enterprise-level data for Vietnam's manufacturing sector conducted in 2003; the result shows that exporting firms are about 4.5 percentage points more technically efficient than non-exporting firms and a ten percentage point increase in the average tariff rate would lead to a 1.5 percentage point reduction the level of enterprise technical efficiency. However, in the Vietnamese context, greater exposure to international trade is not the only factor of improvement in firm performance; the early stages of industrialization, when many unproductive firms have long since exited, also have a greater potential for improving productivity (Hallward-Driemeier et al., 2002). As the first study mentions the relationship between GVC participation and firm technical efficiency in Vietnam, Cong (2010) found that exporting has no significant influence on the technical efficiency of Vietnamese domestic non-state manufacturing SMEs. The results are against mainstream ideas, in which exporting firms are more efficient, but it is similar to the results from other transitional economies (Yang, 2003; Yang & Chen, 2009). The estimated result also indicates that Vietnamese non-state are typed as labour-intensive with low added value; the author also provided many suggestions which help Vietnamese SMEs move up on the value chain and avoid labour-intensive, low skill and low-value-added activities.

Overall, many studies attempt to investigate the relationship between GVC participation and firm'effiency, but there remains a literature shortage in this field. On the one hand, some studies use the GVC participation index through the Input-Output table (database), but they do not focus mainly on pure efficiency indicators like technical efficiency. On the other hand, studies investigate the factor affecting a firm's efficiency through technical efficiency but only link it to integration by importing and exporting data. It is worth emphasizing that Vietnam is integrating into the global value chain more and more deeply through both backward and forward linkages that bring the FDI spillover, cost reduction, and technology transfer for Vietnamese firms. Hence, it needs to be more in-depth research on these linkages in order to have appropriate policies to promote participation in the global value chain for Vietnam's enterprises, especially SMEs. Our study adds to the existing literature in several ways. It will provide academics with a new view of the relationship between GVC participation and firm's efiency in the case of GVC trades, the data about TE and GVCs participation in Vietnam.

Table 1 List of variables adopted from literature.

Variable name	Description	Source
Technical efficiency	The ability of firms to maximize output with a specific number of given inputs	Kim et al. (2012), Assefa Admassie & Matambalya (2002), Lundvall & Battese (2000), Le & Harvie (2010). Applying DEA, Bhandari & Ray (2012)

Capital intensity	The amount of capital used to produce goods	Wadud (2007), De Jorge-Moreno & Rojas Carrasco (2015), Rath (2018)
Domestic Value Added (DVA)	The share of foreign value added in gross exports of the sector that the firm operates in, measuring the backward GVC participation	Epede, M. B., & Wang, D., 2022, Koopman et al. (2014)
Foreign Value Added (FVA)	The share of foreign value added in gross exports of the sector that the firm operates in, measuring the backward GVC participation.	Urata (2022), Anh, D and Anh, V (2020), Kamau (2009)
Export	Firm engagement in exporting activities,	Yazdanfar et al., 2019, Hung et al (2010), Cong (2010)
Import	Firm using imported inputs	Dwivedi (2012), Zhu(2023)
Ownership	Form of ownership	Choi et al., 2017; Khalifah, 2013; Mastromarco & Ghosh, 2009; Otsuka & Natsuda, 2016; Sari et al., 2016; Sheu & Yang, 2005; Suyanto et al., 2014a; Yang et al., 2010; Yasin & Sari, 2022b; Zhang, 2017 ; Walheer & He (2020)
Wage	Average annual wage per worker, proxied for quality of labor force	Cheruiyot (2017), Kashiwagi & Iwasaki (2020)
Location	Location of firms	Yang et al. (2010), Charoenrat et al. (2013)

3. Methodology

3.1. SFA method

The stochastic frontier paradigm can be viewed as a generalization of the classical production function approach, where the optimal allocation in production is a testable restriction rather than a prior assumption usually assumed by the neoclassical production theory.

Stochastic frontier analysis (SFA) is a parametric approach that is widely used in analyzing how the product is deviated from the frontier. This method assumes the stochastic relationship between the inputs used and the actual output. Deviations from the frontier are attributed to inefficiencies as well as the idiosyncratic errors of the data.

3.1.1. *Production function*

Compared to the non-parametric approach of Data Envelopment Analysis (DEA), SFA requires the priori that the functional form of the production function is known. The two most commonly used functional forms for technical efficiency estimation are the **Cobb-Douglas function** and the **Translog production function.**

The Cobb-Douglas function takes the form:

$$y = \beta_0\, x_1^{\beta_1} x_2^{\beta_2} \ldots x_m^{\beta_m}$$

In which x_i is the set of inputs for production, including labour, raw materials, capital, etc. And β_i is the unknown parameters. The liner form of Cobb-Douglas function is

$$\ln(y) = \beta_0 + \beta_1 \ln(x_1) + \beta_2 \ln(x_2) + \cdots + \beta_m \ln(x_m)$$

A more generalized form of production function is expressed in the translog production function, originating from Christensen et al. (1971).

$$\ln(y) = \gamma_0 + \sum_{i=1}^{m} \gamma_i \ln(x_i) + \frac{1}{2} \sum_{j^{\Sigma} i^{\delta}_{ij} \ln} \ln(x_i) \ln\left(x_j\right) \;\; where\ \delta_{ij} \; = \; \delta_{ji}$$

We employ the log-likelihood ratio test to determine which functional form is appropriate to estimate the production of firms. The null hypothesis is that all coefficients of interactions in the translog model equal 0, meaning that **Cobb-Douglas** is the adequate form to gauge a firm's performance. The alternative hypothesis suggests that these coefficients are significantly different from 0, suggesting that Translog model is appropriate to estimate the efficiency.

3.1.2. *Decomposing the technical inefficiency of panel data*

The general form of the stochastic frontier model can be expressed as:

$$\ln(y_i) = \beta_0 + \; \gamma x_{it} + v_i - u_i$$

$$v_i \; \sim \mathfrak{N}(0,\, \sigma_v^2)$$

$$u_i \; \sim \; \mathcal{F}$$

In which $\ln(y_i)$ is the logarithm of the output of the i^{th} productive unit; x_{it} Denotes the vector of outputs, including labour, physical capital, and raw materials, β is the vector of technology parameters regarding each type of input. The error term includes two components: **the measurement error** v_i and **the technical inefficiency (u_i).** Panel data allow us to relax some assumptions related to the relationship between inefficiency and measurement error. We follow the time-varying stochastic frontier model proposed by Battese and Coelli (1995) in which $g(t) = \exp[-\eta(t - T_i)]$, where g(t) represents a set of time dummy variables.

A very important issue in SF analysis is the inclusion in the model of exogenous variables, which are supposed to determine the technical inefficiencies. These variables, which usually are neither the inputs nor the outputs of the production process, but nonetheless affect the productive unit performance, have been incorporated in a variety of ways: i) they may shift the frontier function and/or the inefficiency distribution; ii) they may scale the frontier function and/or the inefficiency distribution; iii) they may shift and scale the frontier function and/or the inefficiency distribution.

Sequential steps of the stochastic production function are explained as follows. Firstly, parameters $\hat{\theta}$ are estimated by maximizing the log-likelihood function $l(\theta)\ where\ \theta = (\beta, \gamma', \sigma_u^2, \sigma_v^2)'$. In the next step, the point estimates of efficiency can be derived using the mean of conditional distribution $f(u_i|\hat{\varepsilon}_i)$ in which $\hat{\varepsilon}_i$ Is the residual from the equation $\hat{\varepsilon}_i = y_i - \hat{\beta} - \widehat{\gamma'}x'_{it}$.

The log-likelihood function assumes that the u_i and v_i are independent of each other. The functional form for n firms is:

$$l(\theta) = \sum_{i=1}^{n} \log\ f_{\varepsilon}(\varepsilon_i|0)$$

Two most common solutions for disentangling the inefficiency are Jondrow et al. (1982) and Battese and Coelli (1995) using the conditional distribution of inefficiency **u** given ε:

$$Eff = \exp(-\hat{u})$$

Where $\hat{u}$ can either $\mathrm{E}(u|\hat{\varepsilon})$ or $\mathrm{M}(u|\hat{\varepsilon})$, depending on the estimating technique. After obtaining the inefficiency from SFA method, we run regression on some determinants derived from the literature.

3.2. *Tracing value-added and GVC participation*

Trade in value-added actually is based on an idea of fragmentation of production. According to the definition of GVCs indicated by Antràs 2020, GVC consists of a series of stages involved in producing a product or service that is sold to consumers, with each stage adding value and with at least two stages being produced in different countries. Therefore, the traditional measure of trade volume does not adequately reflect the contribution of a country to global output. Traditional trade in goods and services has been replaced by outsourcing tasks globally thanks to hyper-specialization based on comparative advantages. The current statistics are grossly incompetent in understanding the country of origin and follow the trade-in value added because the data is not supporting that. So, if there is a new measure which can take into account the components trade and link it with the domestic and foreign value added in the exports, then a clearer picture will be evolved, which can help in developing policies, not just for the trade but for development of the sectors, address skill related issues, employment-related issues, infrastructure related issues.

Regarding the value-added approach, World Input-Output Table has become the main ingredient in decomposing the value contribution of each country (Antràs & Chor, 2022). Several global organizations have made an effort to create an international input-output table popularly known as the multi-regional input-output (MRIO) table, the WorldInput–Output Database (WIOD), the OECD TiVA database, and the Eora Global Supply Chain Database. Figure 1 illustrates the structure of the World Input-Output Table. In this JS x JS matrix, the typical entry Z_{ij}^{rs} represents the value of inputs from industry r in country i (horizontal array) purchased from the industry s of country j (vertical array).

			Input use & value added							Final use			Total use
			Country 1			…	Country J			Country 1	…	Country J	
			Industry 1	…	Industry S	…	Industry 1	…	Industry S				
Output supplied	Country 1	Industry 1	Z_{11}^{11}	…	Z_{11}^{1S}	…	Z_{1J}^{11}	…	Z_{1J}^{1S}	F_{11}^{1}	…	F_{1J}^{1}	Y_1^1
		…	…	Z_{11}^{rs}	…	…	…	Z_{1J}^{rs}	…	…	…	…	…
		Industry S	Z_{11}^{S1}	…	Z_{11}^{SS}	…	Z_{1J}^{S1}	…	Z_{1J}^{SS}	F_{11}^{S}	…	F_{1J}^{S}	Y_1^S
	…	…	…	…	…	Z_{ij}^{rs}	…	…	…	…	F_{ij}^{r}	…	Y_i^r
	Country J	Industry 1	Z_{J1}^{11}	…	Z_{J1}^{1S}	…	Z_{JJ}^{11}	…	Z_{JJ}^{1S}	F_{J1}^{1}	…	F_{JJ}^{1}	Y_J^1
		…	…	Z_{J1}^{rs}	…	…	…	Z_{JJ}^{rs}	…	…	…	…	…
		Industry S	Z_{J1}^{S1}	…	Z_{J1}^{SS}	…	Z_{JJ}^{S1}	…	Z_{JJ}^{SS}	F_{J1}^{S}	…	F_{JJ}^{S}	Y_J^S
Value added			VA_1^1	…	VA_1^S	VA_j^s	VA_J^1	…	VA_J^S				
Gross output			Y_1^1	…	Y_1^S	Y_j^s	Y_J^1	…	Y_J^S	…			

Figure 1 Structure of World Input-Output Table *(Antràs & Chor, 2022)*

A closely-related task is to unpack the sources of value-added embodied in trade data that is observed "as-is", such as in a country's gross exports. The initial effort of unpacked sources of value-added contained in gross exports was presented in the study of Hummels et al. (1998, 2001) about the nature of vertical specialization in the global trade pattern. Since production stages are fragmented elsewhere, a country can use its intermediate inputs to produce its exports. There are two modes of GVC participation, i.e., backward linkage (a country's exports embodying imported content) and forward linkage (a country's exports contained in the importing country's imports). Literature on GVC measurement proposes several ways to compute the value-added in exports (VAX) indicator, embarked on by Johnson & Noguera (2012), and extended on later work by Koopman et al. (2014) for gross-export accounting to deal with double-counting issues of customs data.

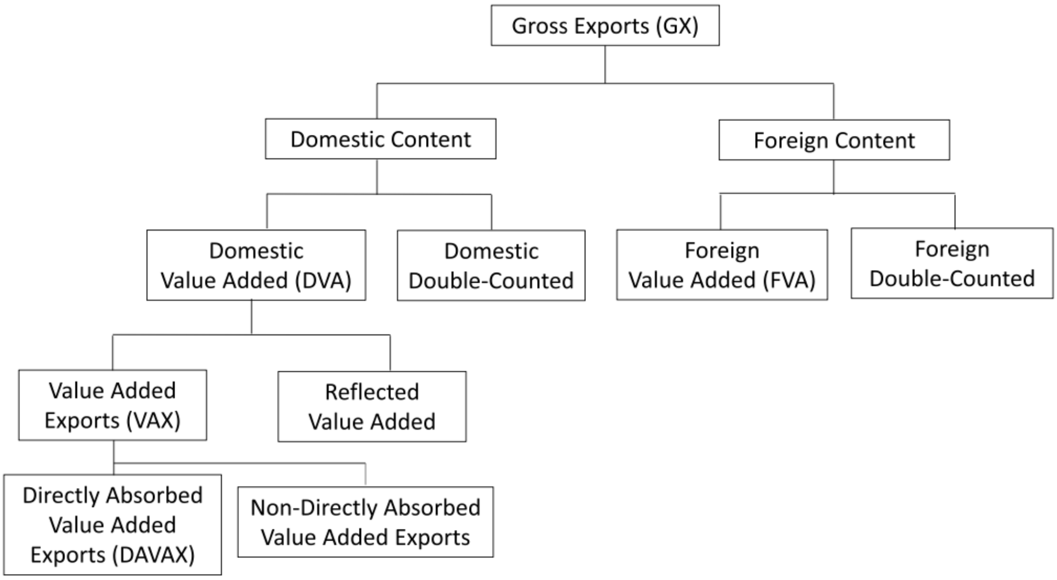

Figure 2 Value – added accounting (Koopman et al., 2014)

3.3. Data collection

3.3.1. Enterprise data

Data on SMEs in Vietnam are obtained from GSO Enterprise Census. This survey is conducted annually by General Statistics Office to assess the overall business performance of Vietnamese firms. Enterprises participating in the survey are distributed in approximately 18 manufacturing sectors,. Enterprises are classified according to the current Vietnam law definition, with micro-enterprises having up to 10 employees, small-scale enterprises up to 100 employees, medium-sized enterprises up to 300 employees, and large enterprises having more than 200 employees. In this study, we adopt the data for 4 years, from 2015 to 2018. It is the period that Vietnam experienced strong economic integration and the trade in value-added became a prevailing concept. Hence, it is interesting to unveil how GVC participation can potentially affect the performance of SMEs.

3.3.2. Global value chain participation data

There are several databases that track the GVC participation of countries at sectoral levels, including UNCTAD – Eora GVC database, GVC WDR by the World Bank, and TiVA database by OECD. In this study, we utilize the TiVA database by OECD, which provides a wide range of indicators to feature the GVC participation at the sectoral level. The 2021 edition of the TiVA database covers 68 economies in the world from 1995 to 2018. The industrial list includes 45 unique industrial activities organized hierarchically based on ISIC Revision 4 (OECD, 2015). The calculation of trade in value-added indicators is based on the Inter-Country Input – Output (ICIO) table compiled according to 2008 System of National Accounts (2008 SNA) concepts. In this study, we use the GVC participation level at the *sectoral level* to understand how SMEs in sectors with different levels of integration in GVC can benefit from sectoral participation in GVC.

To measure *backward participation*, we use the **foreign value-added share of gross exports percentage.** The indicator code is $EXGR\_FVASH_{c,\ i}$ for country c and sector i. The formula for calculating FVA share:

$$DVAsh_{c,i} = \frac{\sum_p EXGR\_DVA_{c,i.p}}{\sum_p EXGR_{c,i.p}} \times 100$$

In which $EXGR\_DVA_{c,i.p}$ is the domestic value added (in USD) in gross export of industry i in country c to country p.

To measure *forward participation*, we use the **domestic value-added share of gross exports percentage.** The indicator code is $EXGR\_DVASH_{c,i}$ for country c and sector i.

$$FVAsh_{c,i} = \frac{\sum_p EXGR\_FVA_{c,i.p}}{\sum_p EXGR_{c,i.p}} \times 100$$

In which $EXGR\_FVA_{c,i.p}$ is the foreign value added (in USD) in gross export of industry i in country c to country p.

3.3.3. *Descriptive statistics*

The final sample includes 568,383 firm-year observations from 2015 to 2018. Table 2 defines key variables used in our model and summary statistics of each variable

Table 2 Descriptive statistics of key variables

Variables	Description	Obs	Mean	Std. dev.	Min	Max
Variables for the production function						
va	Value added, in million VND	567,866	1,086	3,955	0	86,310
labor	Value of physical capital in million VND	567,866	10.77	17.64	1	146
capital	Number of full-time employees	567,866	1,655	10,795	0	671,354
Variables for inefficiency model						
fva_vnm	Foreign value added in gross export, %	567,866	50.43	0.842	0	71.35
dva_vnm	Domestic value added in gross export, %	567,866	49.57	0.842	0	82.68
export	Export = 1 if the firm engages in export activities, = 0 otherwise	0.00259	0.0509	0	1	0.00259
import	Import = 1 if the firm engages in export activities, = 0 otherwise	0.0126	0.112	0	1	0.0126
wage_avg	Average wage per worker, including allowance	567,866	60.04	175.8	0	95,697
cap_em	Capital intensity, measured by average capital per worker	567,866	160.7	1,920	0	461,835
ownD	Ownership = 1 if the firm is private, = 2 if the firm is state-owned, =3 if the firm is with foreign direct investment	568,383	1.043	0.277	1	3
region	Location, =1 if the firm is located in the North, =2 if the firm is located in the Middle, =3 if the firm is located in the South	567,866	1.043	0.276	1	3
size	Firm size, =1 if the firm is micro, =2 if the firm is small, = 3 if the firm is medium	567,866	1.241	0.451	1	3

Note: Authors' calculation, using the GSO Enterprise Census and TiVA OECD. Monetary value in this study is expressed in million VND, 2010 prices.

3.4. Econometric models

We conduct two – stages analysis by firstly estimating the inefficient component [2]from product function and then regressing such inefficiency for some determinants, followed the model introduced by Battese & Coelli (1995) model. In the first stage, we determine the appropriate form of production function to gauge the technical efficiency. The first log – likelihood test[3]suggests that *translog production function is appropriate to understand the technical efficiency:*

$$\ln(y_i) = \beta_0 + \beta_1 \ln(K_i) + \beta_2 \ln(L_i) + \beta_3 time + \beta_4 \ln(K_i)^2 + \beta_5 \ln(L_i)^2 + \beta_6 time^2 + \beta_7 \ln(L_i)\ln(K_i) + \beta_8 \ln(L_i) time + \beta_9 \ln(K_i) time + v_i - u_i$$

In which

y_i = the value added of firm i

K_i = the physical capital of firm i

L_i = ther of employees (full time) at firm i

time = Index for the year

v_i = the error term of firm i due to measurement error, i.i.d $\sim$ $\mathrm{N}(0, \sigma_v^2)$ and independently distributed of u_i.

u_i = the techncial inefficiency of firm i, non-negative. Assumed to be independently distributed of v_i with the truncated normal distribution of $\mathrm{N}(0, \sigma_u^2)$.

To disentangle the effects of global value chain participation and firm characteristics on firm efficiency, we use two equations functions for measuring the impacts of **backward GVC participation (**Model 1) and **forward GVC participation (**Model 2)

$$u_i = \alpha_0 + \alpha_1 FVAsh_i + \alpha_2 import + \alpha_3 export + \alpha_4 \ln\left(cap_{emp_i}\right) + \alpha_5 \ln\left(wage_{avg_i}\right) + \alpha_6 ownership + \alpha_7 region + \alpha_8 size + \tau_i \qquad (1)$$

$$u_i = \alpha_0 + \alpha_1 DVAsh_i + \alpha_2 import + \alpha_3 export + \alpha_4 \ln\left(cap_{emp_i}\right) + \alpha_5 \ln\left(wage_{avg_i}\right) + \alpha_6 ownership + \alpha_7 region + \alpha_8 size + \tau_i \qquad (2)$$

---

[2] First log likelihood test detects whether the inefficiency component is detected in the production function. Second log likelihood test determines whether coefficients of all variables are equal 0 in the inefficiency model.

[3] Third log likelihood test: Two hypotheses, H_0: Cobb – Douglas is the appropriate functional form. H_1: Translog is the appropriate functional form. We test whether the coefficients on pairwise interactions between K, L, time are jointly equal 0. The p-value is 0.0000 and the LR chi2(6) is 137.55, suggesting that *translog is the appropriate functional form.* The estimated result for two models is shown in Appendix I.

In which,

u_i = technical inefficiency, estimated using Battese and Coelli's (1992) estimator.

$FVAsh_i$ = The share of foreign value added in gross exports of the sector that the firm operates in, measuring the backward GVC participation.

$DVAsh_i$ = The share of domestic value added in gross exports of the sector that the firm operates in, measuring the forward GVC participation.

$export_i$ = Dummy variable, equal 1 if the firm engages in exporting activities and 0 otherwise.

$import_i$ = Dummy variable, equal 1 if the firm engages in importing activities and 0 otherwise.

cap_{emp_i}= Average capital per worker, or capital intensity

$wage_{avg_i}$= Average annual wage (including allowance and other labor cost) per worker, proxied for labor quality

$region_i$ = 1 if the firm is located in the North, =2 if the firm is located in the Middle, =3 if the firm is located in the South.

$ownership_i$ = 1 if the firm is private, = 2 if state-owned, = 3 if foreign – owned

$size_i$ = 1 if the firm is micro (less than 10 employees), = 2 if small (less than 100 employees), = 3 if medium (less than 200 employees).

Table 3 Correlation matrix of the pane data

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Value added	1											
2. Capital	0.325***	1										
3. Labor	0.382***	0.279***	1									
4. FVA share	0.0340***	-0.00733***	-0.0689***	1								
5. DVA share	-0.0340***	0.00739***	0.0690***	-0.975***	1							
6. Export	0.0139***	0.0139***	0.0399***	-0.0192***	0.0193***	1						
7. Import	0.0234***	0.0336***	0.0999***	-0.207***	0.207***	0.370***	1					
8. Average wage	0.0669***	0.0210***	0.0215***	0.0122***	-0.0122***	0.00289*	0.0135***	1				
9. Capital intensity	0.0972***	0.433***	-0.00223	0.00863***	-0.00861***	0.00109	-0.000562	0.0386***	1			
10. Ownership	0.194***	0.0914***	0.173***	-0.0144***	0.0145***	0.0277***	0.0603***	0.0681***	0.00844***	1		
11. Size	0.302***	0.203***	0.759***	-0.0869***	0.0872***	0.0309***	0.0978***	0.0266***	-0.00308*	0.148***	1	
12. Region	-0.00701***	-0.0264***	-0.0822***	-0.157***	0.158***	-0.00211	0.0292***	0.00187	0.00215	0.0127***	-0.0674***	1

Note: Authors' calculations, using the GSO Enterprise Census and TiVA OECD. Significant level: * p<0.05, ** p<0.01, *** p<0.001

4. Results and finding

4.1. Technical efficiency and GVC participation

In the first hypothesis test for the existence of inefficiency component since the null hypothesis of non-existence of technical inefficiency is significantly rejected at 1% at 1% level of significance. For both years, the Translog model is more adequate to measure the technical efficiency than Cobb – Douglas function since the null hypothesis is significantly rejected at 1% level of significance. Hence, **translog model is used to gauge the technical efficency of firms.** The third hypothesis test for coefficients of explanatory variables for inefficiency is significantly rejected at 1% for both years. Estimated results for panel data are presented in Table 4. In our model, we conceptualize three modes of GVC participation, in which SMEs can export, import, or undertake both activities. This classification is standardized in many GVC literature by

Table 4 Estimates of stochastic frontier model and technical inefficiency effects model

VARIABLES	Backward participation	Forward participation
Stochastic frontier model		
lnK	0.120***	0.120***
	(0.00128)	(0.00128)
lnL	0.706***	0.705***
	(0.00291)	(0.00292)
dyear	YES	YES
Constant	4.144***	4.204***
	(0.0238)	(0.0248)
Technical inefficiency effects model		
lnwage_avg	-0.475***	-0.466***
	(0.00763)	(0.00736)
lncap_em	-0.196***	-0.192***
	(0.00429)	(0.00418)
importD	-0.604***	-0.582***
	(0.0533)	(0.0510)
exportD	0.224**	0.208**
	(0.107)	(0.104)
fva_vnm	-0.327***	
	(0.00914)	
State-owned	-3.143***	-3.052***
	(0.146)	(0.140)
FDI	-3.859***	-3.751***
	(0.129)	(0.123)

Middle	0.542***	0.536***
	(0.0205)	(0.0201)
South	-0.515***	-0.508***
	(0.0130)	(0.0126)
Small	-0.112***	-0.111***
	(0.0158)	(0.0154)
Medium	-0.157***	-0.155***
	(0.0573)	(0.0559)
dva_vnm		0.363***
		(0.00956)
Constant	19.57***	-14.87***
	(0.460)	(0.476)
Observations	567,866	567,866

Note: Standard errors in parentheses. Significant level: *** p<0.01, ** p<0.05, * p<0.1

Table 4 presents the estimated result of the SFA model to disentangle the relationship between technical efficiency and GVC participation of SMEs. The coefficient on DVA share is 0.363 and significant at 1%, implying that SMEs in sectors with deeper forward participation tends to have low technical efficiency level. It can be explained as Vietnam's integration into GVC mostly dealt with assembling tasks. As these tasks are not required a high technological investment, it underpins the motivation of SMEs to upgrade their technology. As a result, many of them are currently stuck in medium efficiency levels. This finding aligns with results from Dang and Dang (2020) and Korwatanasakul and Hue (2022) which suggest the negative impacts of forward participation on SMEs firms.

Regarding backward participation, our result confirms the positive impacts of backward participation in rising technical efficiency levels. Firms operating in industries with deeper backward linkage tend to have higher level of technical efficiency The coefficient of FVA share is -0.327 in the inefficiency model and significant at 1%. The result implies that backward linkage at sectoral level is important to improve firm ability to use resources.

Our model also disentangles the effect of 3 modes of internationalization. Imported inputs is more likely to increase firm technical efficiency in both model for backward and forward linkage. It supports previous results of Halpern et al. (2015) and Pane and Patunru (2022) in which many studies suggest that using imported inputs can improve firm productivity. According to Singh & Chanda (2021), imported inputs can be cheaper but of higher quality. Moreover, some inputs are not domestically available, which means that backward integration can provide a wider range of inputs for firms. One intriguing finding is that export tends to lower technical efficiency of firms in which SMEs produce simple, less technological – embedded goods. Hence, it undermines their motivation to combine inputs more effectively. If firms participate in both imports and exports, it is still beneficial from backward linkage but for forward linkage, the effect seems to be ignorable. Our empirical result implies the complexity of effects by GVC participation on firm ability to effectively use their inputs. In other words, our finding supports the learning from import hypothesis but challenges the learning from export hypothesis (Atkin et al., 2017; Bas & Strauss-Kahn, 2014; Chen & Tang, 1987; Kasahara & Lapham, 2013; Torres de Oliveira et al., 2021).

We also observe some other determinants of technical inefficiency. Regarding the firm-specific characteristics, capital intensity tends to lower the technical efficiency in which its coefficients in the technical inefficiency model are positive and significant at 1%. The effect of capital intensity supports the finding of Wadud (2007) and (De Jorge-Moreno & Rojas Carrasco, 2015). In fact, providing more capital to workers does not guarantee a higher efficiency level if capital investment is not appropriate and workers are not capable of utilizing such capital effectively. Interestingly, the coefficient on wage suggests that a 1% increase in an annual way can be associated with 8% increase in technical efficiency. One plausible explanation is that manufacturing sectors in which SMEs operate are often labor-intensive, implying that labor is one important aspect of the production process. Higher wage is often associated with higher skills of workers (Li et al., 2019). This result supports the finding of Cheruiyot (2017) and Kashiwagi and Iwasaki (2020) about the positive relationship between human capital quality and technical efficiency.

Regarding firm size, we figure out that large firm size tends to be associated with higher technical efficiency level. In fact, larger firms are more likely to have advanced knowledge, human capital, experience, access to finance, technical know-how to improve production efficiency. This finding aligns with studies by Cuesta (2000); Kim et al. (2012); Charoenrat and Harvie (2013).

Firm ownership is an important determinant of technical efficiency, in which FDI and state-owned are more likely to exhibit high technical efficiency score. Notable, FDI show the highest technical efficiency score, implying the ability to use resources most effectively. In developing countries like Vietnam, FDI firms reap more benefits from internationalization thanks to its strong linkage to international market, openning door for modern technology in production. This connection strengthens the learning activity of FDI firms, much more profound that private/household firms. The outstanding performance of FDI is investigated in a burgeoning of literature on GVC and internationalization of firms (Buraschi et al., 2010; Cheruiyot, 2017; Sari et al., 2016; Suyanto et al., 2012; Yang et al., 2010). Similar to previous research, we find evidence that firms located in different regions report different effects on technical efficiency. In general, firms located in the South are most efficient and others located in the Middle are least efficient. One plausible for this result is that the majority of large industrial clusters are located in the South, with strategic provinces like Ho Chi Minh City, Binh Duong, etc. This set-up enables the interlinkages cross sectors, enabling firms to find buyers or suppliers of services more convenient (Korwatanasakul & Hue, 2022). Furthermore, the concentration of manufacturing firms in the South is associated with better infrastructure catering for industrial development. By contrast, less cross-sector linkage in the Middle and unfavorable conditions related to weather, infrastructure, etc. prevent SMEs in the Middle climbing up on technical efficiency.

4.2. Robustness check

We conduct the robustness check by analyzing how GVC participation has implications for SMEs in different regions and different forms of ownership.

The estimated result for backward linkage and forward linkage regarding three regions are illustrated in Table 5 and Table 6. We find evidence that FVA share are positively correlated to technical efficiency, confirming the previous result of learning from import. SMEs in the Middle can reap larger effect from sectoral backward linkage than SMEs in other regions. By contrast, DVA are found to be negatively linked to technical efficiency, and this effect is most deteriorating for firms in Middle.

Imported inputs are beneficial to improve the efficiency level. Export tends to lower technical efficiency, but the result is not statistically significant. We highlight the strong differences of technical efficiency for different forms of ownership, especially firms in the North. Firm size has significant impacts for models with SMEs in North but not for firms in Middle. Similar to previous estimate, capital tensity and labor quality significantly impact the technical efficiency.

Table 5 Estimates of stochastic frontier model and technical inefficiency effects model for backward participation for firms in different regions

VARIABLES	**North**	**Middle**	**South**
Stochastic frontier model			
lnK	0.137***	0.108***	0.110***
	(0.00148)	(0.00396)	(0.00206)
lnL	0.691***	0.792***	0.722***
	(0.00485)	(0.0124)	(0.00386)
dyear	YES	YES	YES
Constant	3.114***	2.870***	4.646***
	(0.0282)	(0.0642)	(0.0382)
Technical inefficiency effects model			
lnwage_avg	-1.566***	-1.667***	-0.338***
	(0.0729)	(0.169)	(0.00581)
lncap_em	-0.424***	-0.349***	-0.184***
	(0.0246)	(0.0446)	(0.00460)
importD	-0.840**	-4.921**	-0.610***
	(0.346)	(2.318)	(0.0447)
exportD	0.564	1.203	0.122
	(0.523)	(1.704)	(0.110)
fva_vnm	-0.265***	-0.452***	-0.374***
	(0.0270)	(0.0703)	(0.0118)
State-owned	-6.671***	-1.587*	-3.250***
	(0.726)	(0.842)	(0.177)
FDI	-21.56***	-1.855**	-2.509***
	(3.902)	(0.848)	-0.0867
Small	-0.472***	0.254	-0.0544***
	(0.0719)	(0.158)	(0.0173)
Medium	-0.755***	-0.367	-0.0704
	(0.269)	(0.538)	(0.0609)
Constant	16.32***	25.71***	21.79***
	(1.347)	(3.502)	(0.600)
Observations	205,271	28,604	333,991

Note: Standard errors in parentheses. Significant level: *** p<0.01, ** p<0.05, * p<0.1

Table 6 Estimates of stochastic frontier model and technical inefficiency effects model for forward participation for firms in different regions

VARIABLES	**North**	**Middle**	**South**
Stochastic frontier model			
lnK	0.137***	0.108***	0.110***
	(0.00148)	(0.00396)	(0.00206)
lnL	0.690***	0.792***	0.722***
	(0.00485)	(0.0124)	(0.00386)
dyear	YES	YES	YES
Constant	3.148***	2.870***	4.646***
	(0.0281)	(0.0642)	(0.0382)
Technical inefficiency effects model			
lnwage_avg	-1.540***	-1.667***	-0.338***
	(0.0681)	(0.169)	(0.00581)
lncap_em	-0.413***	-0.349***	-0.184***
	(0.0229)	(0.0446)	(0.00460)
importD	-0.823**	-4.921**	-0.610***
	(0.330)	(2.318)	(0.0447)
exportD	0.542	1.203	0.122
	(0.505)	(1.704)	(0.110)
State-owned	-6.501***	-1.587*	-3.250***
	(0.690)	(0.842)	(0.177)
FDI	-20.35***	-1.855**	-2.509***
	(3.092)	(0.848)	(0.0867)
Small	-0.473***	0.254	-0.0544***
	(0.0697)	(0.158)	(0.0173)
Medium	-0.753***	-0.367	-0.0704
	(0.262)	(0.538)	(0.0609)
dva_vnm	0.348***	0.452***	0.374***
	(0.0306)	(0.0703)	(0.0118)
Constant	-14.28***	-19.48***	-15.63***
	(1.545)	(3.545)	(0.586)
Observations	205,271	28,604	333,991

Note: Standard errors in parentheses. Significant level: *** p<0.01, ** p<0.05, * p<0.1

We disentangle effects of GVC participation on technical efficiency for SMEs with three forms of ownership and illustrate in Table 7 (for backward linkage) and Table 8 (for forward linkage).

Empirical evidence supports the baseline model, in which SMEs operating in sectors with higher level of backward participation achieve more efficiency gain while higher sectoral forward linkage is linked to lower efficiency level. Different forms of GVC integration (import, export, or both) have different effects on technical efficiency. The result is statistically significant for private/household group and FDI group, supporting the result of baseline model. For other internal factors of firm, capital intensity is essential to rise efficiency level of SMEs, especially the private/household category as this category often reports low capital availability as the most important barrier to increase the production efficiency (Dinh Chuc et al., 2019; OECD, 2021). Larger firm size can unlock more gains from improving production efficiency.

Table 7 Estimates of stochastic frontier model and technical inefficiency effects model for backward participation for different legal status

VARIABLES	Private/Household	State-owned	FDI
Stochastic frontier model			
lnK	0.132***	0.108***	0.0699***
	(0.00110)	(0.00396)	(0.00677)
lnL	0.677***	0.792***	0.531***
	(0.00284)	(0.0124)	(0.0212)
dyear	YES	YES	YES
Constant	3.660***	2.870***	6.745***
	(0.0169)	(0.0642)	(0.0923)
Technical inefficiency effects model			
lnwage_avg	-0.684***	-1.085***	-0.929***
	(0.0154)	(0.0680)	(0.0492)
lncap_em	-0.290***	-0.0763**	-0.0271
	(0.00798)	(0.0322)	(0.0260)
importD	-1.267***	0.0471	-0.387*
	(0.113)	(0.271)	(0.217)
exportD	0.455**	0.142	1.607***
	(0.200)	(0.596)	(0.361)
fva_vnm	-0.267***	-0.456***	-0.243***
	(0.0119)	(0.0710)	(0.0494)
Middle	0.821***	0.559***	1.260***
	(0.0349)	(0.202)	(0.259)
South	-0.814***	-1.215***	-0.0151
	(0.0253)	(0.149)	(0.0893)
Small	-0.337***	-0.794***	-1.022***
	(0.0285)	(0.163)	(0.132)
Medium	-0.561***	-1.298***	-1.019***
	(0.108)	(0.277)	(0.245)
Constant	15.80***	29.80***	16.99***
	(0.597)	(3.605)	(2.493)
Observations	553,654	4,157	10,055

Note: Standard errors in parentheses. Significant level: *** p<0.01, ** p<0.05, * p<0.1

Table 8 Estimates of stochastic frontier model and technical inefficiency effects model for forward participation for firms in different regions

VARIABLES	Private/Household	State-owned	FDI
Stochastic frontier model			
lnK	0.132***	0.0683***	0.0699***
	(0.00111)	(0.0104)	(0.00677)
lnL	0.677***	0.515***	0.531***
	(0.00284)	(0.0322)	(0.0212)
dyear	YES	YES	YES
Constant	3.683***	6.963***	6.745***
	(0.0176)	(0.168)	(0.0923)
Technical inefficiency effects model			
lnwage_avg	-0.672***	-1.085***	-0.929***
	(0.0152)	(0.0680)	(0.0492)
lncap_em	-0.284***	-0.0763**	-0.0271
	(0.00785)	(0.0322)	(0.0260)
importD	-1.233***	0.0471	-0.387*
	(0.110)	(0.271)	(0.217)
exportD	0.430**	0.142	1.607***
	(0.196)	(0.596)	(0.361)
Middle	0.813***	0.559***	1.260***
	(0.0344)	(0.202)	(0.259)
South	-0.807***	-1.215***	-0.0151
	(0.0249)	(0.149)	(0.0893)
Small	-0.330***	-0.794***	-1.022***
	(0.0280)	(0.163)	(0.132)
Medium	-0.547***	-1.298***	-1.019***
	(0.106)	(0.277)	(0.245)
dva_vnm	0.297***	0.456***	0.243***
	(0.0125)	(0.0710)	(0.0494)
Constant	-12.37***	-15.79***	-7.342***
	(0.630)	(3.508)	(2.452)
Observations	553,654	4,157	10,055

Note: Standard errors in parentheses. Significant level: *** p<0.01, ** p<0.05, * p<0.1

5. Conclusion and implications

5.1. Conclusion

Our study is among the first effort to highlight the role of GVC participation in two forms, i.e., backward participation and forward participation, in improving the technical efficiency of SMEs firm in Vietnam. Our result suggests that GVC participation is crucial to raise the technical efficiency of firms. In addition, wages can impact the technical efficiency of firms in which higher wages imply a higher skilled labour force. Firm size and location impacts on firm technical efficiency are somehow misleading.

The study has both practical and theoretical contributions. Regarding the theoretical contribution, we add to the literature on technical efficiency the new trend of international economics. Increasing international economic integration encourages firms to participate in global production networks. Besides the leading role of multinational corporations, SME participation is essential for many developing countries where SMEs are the backbone of the economy. Hence, it is necessary to look at the linkage between SME performance and its international economic integration. Our result employes the new approach of trade in value added to quantify impacts on technical efficiency, distinguishing between forward participation and backward participation. The practical implications lie in the lessons that we can provide to businesses and policymakers. Especially for SMEs, improving labour quality is the most important aspect of raising technical efficiency. Utilizing foreign inputs efficiently can reduce costs to some extent. To spur the benefits of forward participation rather than its negative impact, upgrading technology and increasing the firm's knowledge are crucial to increase the value-added derived from the GVC participation, thus enabling the larger benefit of learning from doing. Furthermore, during years of crises, exposure to the international market can somewhat reduce technical efficiency. Hence, SMEs should carefully consider their operation and track the supply chain regularly to prevent the disruption of production caused by a lack of resources.

5.2. Policy implications

The study provides useful policy implications for governments to design policy targetting increasing technical efficiency for SMEs. New policies can target on following aspects.

Build a high-skilled national workforce: In general, the labor force quality of SMEs is often lower than large firms. Hence, improving labor quality on a national scale is beneficial to SMEs. Basic skills such as language and IT skills are of special needs in recent years, which is an enabler for acquiring new advanced technology in order to boost technical efficiency. To foster skill development and enable SMEs to thrive in global value chains (GVCs), the government can implement nationwide training programs. These initiatives can encompass general training as well as specialized programs targeting advanced skills in strategic industries. Key areas of focus may include technological literacy, advanced language skills, and other relevant competencies. Prioritizing skills for highly integrated GVC sectors will empower SMEs to elevate their roles and contribute higher value-added functions along the value chains. In our study, the workforce holds a critical role in boosting technical efficiency.

Enhancing the role of forward participation of key sector: Forward participation has negative impacts on technical efficiency for SMEs due to the fact that SMEs often supply low-value-added goods to the global market. The simple production process also discourages them from upgrading technology to enhance technical efficiency. It is a complicated issue in which export orientation seems to be detrimental to SME's ability to maximize efficiency. It calls for cautious trade policy design toward encourage the upgrading along the value chain. In other words, SMEs should be encouraged to export new and innovative products, improve the production process, etc. The government can provide support such as financial support to create incentives for SMEs to adopt modern technologies. Opening new market opportunities and helping SMEs to learn from other countries are viable measures.

Designing policies toward imported quality input for production: Imported input has been found to have positive impact on SMEs. However, promoting imports can increase the dependence on foreign supply, making SMEs more vulnerable to global fluctuation, especially during COVID-19 and geopolitical intension (Audretsch & Belitski, 2021). Therefore, the government should promote a high-quality and resilient supply chain, targeting on providing high quality inputs for production.

Increase procurements to encourage SMEs to supply their products: Empirical analysis shows that state-owned enterprises can be more beneficial from supplying to the government. The government can spur this positive effect by encouraging SMEs production and purchase from them. It enables the stable income sources while help the government support SME activities even better.

Connect business supporting organizations with local firms: Services like logistics, tax consulting, and strategic guidance are vital in enhancing the competitiveness of SMEs. By providing professional and comprehensive business support, SMEs can overcome challenges and create a favorable environment for their growth and success.

Promote the business environment: Enhancements in regulatory frameworks for contract enforcement, anti-trust measures, customs procedures, and cross-border data exchanges are crucial. Additionally, improving the national information and communication technology (ICT) system is essential to ensure seamless connectivity and simplify the search process for MNCs seeking suitable locations and suppliers. Besides, policies should be implemented to facilitate SMEs' access to formal credit. This would enable SMEs to secure larger funds at preferential interest rates, reducing their financial burden while fostering investment in research and development (R&D) activities and innovative solutions. Many SMEs have expressed that the lack of access to formal credit hampers their ability to expand and innovate.

Adopting and innovating technology are critical to the success of SMEs in the process of internationalization: Whether they are producing directly for foreign buyers or supplying large firms that are doing so, SMEs need to be using the latest technologies to generate efficient and high-quality products and to achieve high levels of labor productivity. Technologies are classified into three main categories: supply–side technology policies, demand-size technology policies and systemic technology policies. In terms of supply–side technology, the government can encourage SMEs to adopt global technologies to improve their quality standards as well as reduce obsolete equipment. In terms of demand size, patent policy, antitrust policy, and anticorruption can be beneficial for creating incentives for better technology as it reduces the lobbying power of interest groups. Government procurement of SMEs can be a good measure to encourage the performance of SMEs. Symmetric technology policy calls for collaboration between SMEs and research groups to increase their adoption of the latest technology and more efficient production processes.

5.3. Limitations and future research

Our study has several limitations. Firstly, we are not able to quantify the GVC linkage and firm efficiency in a longer strand of time, especially in recent years of COVID-19 and Russia – Ukraine war. Future research can disentangle this interlinkage by exploring a larger dataset. Secondly, our study does not include interaction terms to understand the moderating effect of each factor. Furthermore, new studies can examine the new trend of sustainability and its impact on technical efficiency. The trend of sustainability encourages the use of new materials, which can affect the value added by SME firms.

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