

Technical inefficiency of the manufacturing sector in Laos: a case study of the firm survey

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Abstract

Purpose – This study aims to unlock the path of growth for sustainable economic development and accomplish the government's vision 2030 by ameliorating the productivity of the manufacturing sector in Laos.

Design/methodology/approach – This study applied cross-sectional data of 2,009 firms from the national firm survey, namely the Economic Census Survey (ECS), in 2012/13 in addition to employing the stochastic frontier analysis (SFA) to assess the production frontier and factors behind the technical inefficiency to arrive at policy recommendations.

Findings – The study found that the efficiency level varied across subindustries with an average of 72.51% in full potential production. Out of the five classified groups, Sub4 (chemical and plastic) was found to be the most efficient manufacturer, while the rest in order are Sub1 (food and beverage), Sub5 (furniture and others), Sub2 (garment and textile), and Sub3 (paper and printing), providing the evidence to improve the technical efficiency. This study discovered that the firm's size, accounting system and credit access are crucial to enhancing the production efficiency of all sampling firms. However, these factors might be subject to specific industries.

Practical implications – For the implication to the business community and policymakers, the findings of this study could be a reference in terms of which areas they should concentrate on to improve the technical efficiency as a part of productivity in the manufacturing industry. For instance, it suggests that firms could improve their production efficiency by introducing the accounting system, laborers' skills (education of managers) and engaging in international trade activities. Additionally, it asks policymakers to help private firms by improving the infrastructure, credit access, training and trade facilitation.

Originality/value – It is believed that, as the major contribution in Lao literature, this study is the first research applying the largest data from the national survey – the Lao ECS – examining the technical efficiency in the manufacturing sector in the country, and overcoming the gap of the previous research which recruited few policy variables and applied a small sample size in one specific industry. Therefore, the findings of this study impart more insights into the analysis, providing more effective and credible recommendations to policymakers and firms to improve their technical efficiency and, consequently, their competitiveness.

Keywords Manufacturing sector, Stochastic frontier analysis, Laos, Technical inefficiency

Paper type Research paper

1. Introduction

Over the last two decades, the economies of certain low-income countries in Asia – such as China, India, Thailand and Indonesia – have witnessed rapid growth and a subsequent increase in their income per capita, propelling them into the list of higher-income countries, as highlighted by the [Asian Development Bank \(2017\)](#). The high record of economic growth has been predominantly attributed to capital investment and productivity growth

JEL Classification — D22, D24, D25

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(Asian Productivity Organization, 2016, p. 77). However, many developing countries in Asia may encounter challenges in the years ahead as they may not be able to employ the same growth model that heavily depends on capital investment for their transition to higher income levels (Asian Development Bank, 2017). Besides, several emerging and low-income economies have been threatened by the recent slowdown of productivity growth due to the global financial crisis of 2007–2008 (Adler *et al.*, 2017; OECD, 2016). Laos is not an exception. The country's economic growth has been experiencing a slowdown in recent years from 8.8% in 2010 to 5.5% in 2019 (Lao Statistics Bureau, 2011, 2020). Nevertheless, over the last two decades, the high record of Lao economic growth with 7.6% annually during 2000–2019 was strongly influenced by a large capital inflow of foreign direct investment (FDI), especially in the resource sector (mining and hydropower), since the early 2000s. As a result, the resource sector owns the largest share of total export and highest rate of labor productivity – which is 12 times higher than the non-resource sector. In contrast, employment in the resource sector is less than 1% of the total. This sector also suffers from a limited stock and is, thus, vulnerable to commodity prices, further facing a drawback on the non-resource sector due to the Dutch disease manifesting through the exchange rate. Therefore, the heavy dependence on resource industries as capital intensive investment leads to the unsustainability of the Lao economy in the long term. Developing the non-resource sector, especially the manufacturing sector, should be the alternative to drive Lao economic development in the future since its share in the gross domestic product (GDP) is still meager (around 7–8% during the last decade); similarly, the successful high-income developing countries generally had a high share of the manufacturing industry in their economies, 23.6% of the GDP (UNCTAD, 2021). Moreover, developing the manufacturing sector can additionally assist the Lao government to fulfill its future goals in upgrading the status of the country from the lower-middle-income to the upper-middle-income level by 2030 (Ministry of Planning and Investment, 2016).

However, there still remains a challenge for Lao policymakers to ensure the stable growth of manufacturing since its productivity had declined overall in the previous years, as surveyed [1] by Maurer *et al.* (2019, p. 2). This had further deteriorated the growth of the Lao economy and its overall productivity. According to the Asian Productivity Organization (2020, p. 52), the productivity of the Lao economy, indicated by the total factor productivity (TFP), had reduced by 1.1% during the 2010–2018 period along with its neighbors, including Cambodia and Myanmar. Note that the TFP is measured by the GDP or output per unit of combined inputs such as capital and labor, representing the overall efficiency of a country's production (Asian Productivity Organization, 2020, p. 52). It is believed that the lack of skilled and educated labor limits the growth of productivity as well as the competitiveness of enterprises in Laos (Lao National Chamber of Commerce and Industry, 2020, p. 8). However, the TFP level of Lao manufacturing firms is still relatively high compared to its regional peers although its labor productivity is poorer due to the low skilled laborers and low capital intensity (World Bank Group, 2018). As a whole, Lao manufacturing is less competitive in the region because of its low labor productivity – lower than Cambodia's by 10% and almost half of that of Vietnam (World Bank Group, 2018, p. 9). Fortunately, the labor productivity in the garment industry is comparable to its regional peers, whereas the same in food processing is much lower. Apart from the laborers' skills, the slowdown in productivity could be attributed to the business climate, as the ease of conducting business in Laos by global ranking has been deteriorating. In 2019, the country was demoted to the 154th position, which is worse than its global rank in 2015 (139th) (World Bank, 2016, 2020). Therefore, the growth of manufacturing enterprises in Laos is highly likely to be constrained by multiple factors, especially the poorly equipped workforce, tax rates, access to financing, tax regulations, inadequate supply of infrastructure and corruption (World Economic Forum, 2018).

Accordingly, it is necessary to restore the growth of manufacturing and secure this sector as the driver of future Lao economic growth. This leads to the motivation of the current study

which aims to unlock the path of growth for sustainable economic development and accomplish the government's vision 2030 by ameliorating the productivity of the manufacturing sector in Laos. However, due to the limitation of the data, this study focuses the analysis on the technical efficiency only as a component of productivity where the other is the allocative efficiency (Farrell, 1957). The main hypothesis seeks to examine the influences of the firm's specific factors on the technical inefficiency, such as foreign investment, the firm's size and age, export activity, laborers' skills, location and heterogeneity – which are found to be the cause of the technical inefficiency in the extant literature of neighboring countries. To this end, this study applied cross-sectional data from the national firm survey, namely the Economic Census Survey (ECS), in 2012/13 in addition to employing the stochastic frontier analysis (SFA) to assess the production frontier and factors behind the technical inefficiency to arrive at policy recommendations.

It is believed that, as the major contribution in Lao literature, this study is the first research applying the largest data from the national survey – the Lao ECS – examining the technical efficiency in the manufacturing sector in the country and overcoming the gap of the previous research which recruited few policy variables and applied a small sample size in one specific industry. Therefore, the findings of this study impart more insights into the analysis, providing more effective and credible recommendations to policymakers and firms to improve their technical efficiency and, consequently, their competitiveness. For instance, it suggests that firms could improve their production efficiency by introducing the accounting system, laborers' skills (education of managers) and engaging in international trade activities. Additionally, it asks policymakers to help private firms by improving the infrastructure, credit access, training and trade facilitation. The paper is structured as follows: The background and identified problems are presented in the first section, while the available literature and associated limitations are highlighted in Section 2. Section 3 describes the methodology, including data sources, and the econometric results are discussed in Section 4. The conclusion is presented in the last section.

2. Literature review

It must be acknowledged that it is relatively difficult to find previous studies on the productivity or technical inefficiency of the Lao manufacturing industry based on quantitative methods such as data envelopment analysis (DEA) or SFA. Several studies can be found related to agriculture, but those of the manufacturing industry are rare. To the best of my knowledge, only one paper is available – a study by Vixathep (2011) – for which DEA was used to analyze the growth of productivity of 33 garment firms in 2004–2005. The key finding reveals that the productivity of sampling garment firms decreased by around 40% during the period studied (p. 102). Such a significant decline within two years was predominantly attributed to a decrease in technical progress due to the demand shock as claimed by the author. Vixathep further investigated the inefficiency model, including the factors of the firm's specifics such as its age, ownership, capital intensity and proportion of managerial employees. As depicted by the results, only the variable of staff share was found to affect the efficiency, indicating a shortage of managerial employees in the garment firms (p. 105). Other studies have touched upon the productivity analysis related to the Lao economy at the macro level but have failed to provide details of the analysis and policy recommendations at the micro-level or for manufacturing industries. Nevertheless, their findings could confirm that the source of growth for the Lao economy was primarily from the capital input, especially from the FDI in the resource sector rather than productivity. For instance, Kao (2013, p. 255), who estimated the TFP growth as an indicator of national productivity for ten Association of Southeast Asian Nations (ASEAN) countries in 1999–2001, presented that the TFP growth contributed around 1.024% points per year for the economic growth of Laos, whereas 4.5% points were from capital growth and

1.32% points from labor growth. Unfortunately, substantial conclusions cannot be drawn from this study since it lacks a detailed analysis. With a similar result, [Nolintha and Yee \(2015\)](#), who used the time series data of the Lao economy during 1991–2010 based on the ordinary least square (OLS) estimation, revealed that the growth of the Lao economy is predominantly influenced by capital input rather than labor input, especially by the FDI in the resource sector. The TFP growth is claimed to contribute negligibly to the output growth by merely 0.03% points (p. 64). As mentioned, there are more studies on agriculture that have applied the frontier and inefficiency model, including [Boundeth et al. \(2012\)](#) and [Viengpasith et al. \(2012\)](#) in the case of maize; [Supaporn \(2015\)](#) in the case of sugarcane; [Soukhamthath and Wong \(2016\)](#) in the case of cassava; and [Inthavong \(2005\)](#), [Phetsamone \(2012\)](#), and [Sayavong \(2018\)](#) in the case of rice production. Since this study was focused solely on the manufacturing industry, these have not been included in the review.

Likewise, several studies of the manufacturing industry in the Asian region such as Bangladesh, Pakistan, Indonesia, Malaysia, Vietnam and Thailand based on the SFA and DEA methodology were executed. In the case of Vietnam, the means of the technical efficiency level were estimated to be 50–71.2% ([Dinha et al., 2020](#); [Minh et al., 2007](#); [Pham et al., 2010](#); [Vu, 2016](#)). The influential factors on technical efficiency in the manufacturing industry are varied across the literature. [Vu \(2016\)](#), for instance, found that the export is a matter of technical efficiency but not the infrastructure for FDI manufacturers. On the other hand, [Le and Harvie \(2010\)](#) reveal that the infrastructure is the case influencing the technical efficiency but not the export-related activity for small and medium enterprise (SME) manufacturers. Besides, factors like foreign ownership and the firm's age and size are considered to commonly influence the production efficiency of the Vietnamese manufacturing industry, as foreign-invested or larger firms are occupied by advanced technologies and higher production skills. Evidence is also available of heterogeneity in the technical efficiency among subindustries and different locations. Similarly, in Thailand, [Charoenrat and Harvie \(2014\)](#) discovered that the firm size and age, location, type of firm ownership, foreign investment and export activity were significantly affecting the technical efficiency of SME manufacturing firms. They also proclaimed that skilled labor and government assistance were other factors behind the efficiency improvement, especially for medium-sized enterprises. Financial assistance, income tax exemption, duty privilege, technical, managerial and training assistance comprised the major Thai support for SMEs during the studied period. On average, the technical efficiency level of Thai SME manufacturers was about 50–57%. Upgrading laborers' skills via educational and training programs is generally recommended to improve the production efficiency in the country since most SME manufacturing is labor-intensive, particularly in the garment and food processing industries. [Noor and Siang \(2014\)](#) revealed that factors such as salaries and wages per worker, research and development (R&D) spending, training spending, ratio of educated labor and size are all relevant to the technical efficiency for Malaysian SME manufacturers. In general, the technical efficiency is estimated to be around 56.2%. Unlike the previous study, [Margono and Sharma \(2004\)](#) included more firm characteristics in the efficiency model investigated in four Indonesian manufacturing industries, namely, food, textile, chemical and metal. They found that the factors such as size, location, ownership and age significantly affect technical efficiency but these results vary across industries. For instance, larger sizes notably affect the efficiency in all sampling industries except food, whereas private manufacturers are more efficient than the public ones in all sectors except the textile industry. The study estimates the average technical efficiency to be 55.87%.

3. Methodology and data source

3.1 Methodology

The SFA method was applied which is mainly grounded on the econometric methodology ([Coelli et al., 2005](#)). There are two models for the estimation. The first one is the stochastic

production frontier (equation 1), while another is the technical inefficiency model (equation 2). Both models are simultaneously estimated at once to produce the results. In principle, the first model employs the key factors of production like previous studies comprising capital (K_i), labor (L_i) and materials (M_i). The specification of model 1 is as follows:

$$\log Y_i = \beta_0 + \beta_1 \log K_i + \beta_2 \log L_i + \beta_3 \log M_i - u_i + v_i \quad (1)$$

where Y_i is the total output (sale) in local currency (Lao Kip) for firm i ; K_i is the capital investment or fixed cost in local currency (Lao Kip) for firm i ; L_i is the total labor use in numbers for firm i ; M_i is the material investment or variable cost in local currency (Lao Kip) for firm i ; u_i is the nonnegative random or technical inefficiency; and v_i is a well-behaved random variable.

Equation 2 identifies the potential candidates of factors behind the technical inefficiency (u_i) model. The selection of potential variables or a firm's specific characteristics for the inefficiency model chiefly follows the previous studies and the availability of data is based on the ECS questionnaire. A majority of the previous studies included variables in the model subjected to the basic firm's characteristics such as size, age, ownership and location, subindustries, and availability of data in the enterprise survey. For instance, some enterprise surveys include questions of international standard certificates such as ISO 900 or ISO 2008, R&D, investment climate, and government assistance, which can be potential variables for the inefficiency model. Here, for the ECS, the candidate variables include the firm's specific characteristics such as the size, age, education of the manager, firm's ownership, use of accounting system and information technology (IT). Apart from these, the variables of subindustries, location and credit access are captured in the inefficiency model as well. The location effect, as represented by different provinces, is expected to represent the cost efficiency of transportation and other unobservable conditions such as rigidities of institutions, spillover benefits from agglomeration and domestic markets concerning the production efficiency of firms in different areas (Charoenrat and Harvie, 2013, p. 386). There are 17 provinces in total where the infrastructure development is relatively better in the capital city (Vientiane Capital) and urban area whereas it is poorer in the mountainous areas in the northern region of Laos. In 2017, for instance, the percentage of paved roads in Vientiane, the capital city of Laos located in the central region, was the highest (40.2%), while it was low in provinces such as Phongsaly (10.5%) and Huaphanh (13.4%) in the north region.

$$\begin{aligned} \log u_i = & \delta_0 + \delta_1 FIRM SIZE_i + \delta_2 \log AGE_i + \delta_3 \log EDU_MANAGER_i \\ & + \delta_4 FOREIGN_OWN_i + \delta_5 EXPORT_i + \delta_6 ACCOUNT_i + \delta_7 CREDIT_i \quad (2) \\ & + \delta_8 IT_i + \delta_9 SUB_i + \delta_{10} PROVINCE_i + \epsilon_i \end{aligned}$$

where u_i is the firm-specific technical inefficiency; $FIRM SIZE_i$ is a dummy variable for firm i , with a value of 1 if the firm is of a small size and 0 if it is not; AGE_i is the age of the firm i in years; $EDU_MANAGER_i$ is a dummy variable for firm i , having a value of 1 if the manager finished an undergraduate or higher degree and 0 if they did not; $FOREIGN_OWN_i$ is a dummy variable for foreign ownership, possessing a value of 1 if the firm i is owned by foreign investment and 0 if it is not; $EXPORT_i$ is a dummy variable for firm i , with a value of 1 if the firm is an exporter and 0 if it is not; $ACCOUNT_i$ is a dummy variable for the accounting system, with the value being 1 if the firm uses the standard accounting system and 0 if it does not; $CREDIT_i$ is a dummy variable for fund access, with a value of 1 if the firm accessed loans from banks as a source of funds and 0 if it did not; IT_i is a dummy variable for IT, scored 1 if the firm uses the internet and 0 if it does not; SUB_i is a dummy variable for

different groups of industries (five subindustries); $PROVINCE_i$ is a dummy variable for different locations at the provincial level (17 provinces); and ϵ_{it} is the well-behaved error term.

3.2 Data source

This study used cross-sectional data from the ECS in 2012/13; cross-sectional data refer to when several firms can be observed at only one point in time. The ECS 2012/13 is the second survey in Laos conducted by the Lao Statistics Bureau (LSB) during May 10–30, 2013 (Lao Statistics Bureau, 2015a), while the first survey was in 2006. The ECS is a nationwide enterprise survey, carried out every five years, including all establishments regardless of whether they are legally registered. The establishments include profit and nonprofit institutions in economic and related sectors. For the purpose of this study, nonprofit institutions such as the military, police and family businesses were excluded from the analysis. For the profit institution, there were 126,913 establishments in total; of which, 15,573 firms are in the manufacturing industry, constituting 12% of the total. Firms in the service sector own the largest share of 85%, while the agricultural, construction, electricity and mining sectors form the remainder. To classify the definition of different industries within the ECS, the Lao Standard Industrial Classification (LSIC) with five digits is applied. LSIC is compatible with the International Standard Industrial Classification (ISIC).

Most of the Lao manufacturing firms comprise micro and small enterprises and, as such, there was a relatively small number of samples for the empirical analysis when compared with the studies in neighboring countries [2]; therefore, this study increased the number of samples by relaxing the definition of a small size enterprise to take an account of firms with 4–50 employees instead of 6–50 employees – as defined by the Lao Government (2017, p. 2). Medium-sized enterprises are those with an annual average number of employees between 51 and 99 persons. Therefore, large firms are those which employ more than 99 persons. As a result, more than 75.23% of firms are excluded from the analysis because they are regarded as family businesses, referring to a firm that employs less than four employees. After filtering the data, the final sample of 2,009 firms or observations was used for the analysis. Table 1 reports the summary statistics for the variables used for the frontier production model and inefficiency model. Additionally, this study utilizes the ISIC to classify the manufacturing into five major groups of subindustries to investigate the issue of heterogeneity, including Sub1 (LSIC:10111-12090) or a group of food, beverage, and tobacco; Sub2 (LSIC:13111-15203) or a group of garments and textiles; Sub3 (LSIC:16100-18120) or a group of paper and printing; Sub4 (LSIC:19101-23999) or a group of chemicals and plastics; and Sub5 (LSIC:24109-33140) or a group of other industries including furniture, electronics, and others.

4. Empirical results and discussion

Before obtaining the results for equations (1) and (2), a test – to select the functional form of the production model for the whole sample and by groups of subindustries – was executed since previous studies in the neighboring countries of Laos revealed the evidence of heterogeneity. Accordingly, we utilized the translog function for the whole sample and all subindustries, as the test of log-likelihood indicates the rejection of the null hypothesis for the designation of the function as displayed in Table 2. The econometric results for all models are reported in Table 3. Note that only the values of coefficients that passed the statistical test at 1, 5 and 10% are displayed. First, the gamma value (γ), which illustrates the variance in the stochastic frontier, is ranked from 0.1110 to 0.9722 for all samples and subindustries, indicating that the percentages of the difference between the observed output and production frontier is generated from technical inefficiency rather than random variability. The gamma

Variable	Obs	Mean	Std. Dev	Min	Max
<i>Frontier production model</i>					
logY	2,009	16.3477	1.2997	9.9035	19.1138
logK	2,009	18.0169	2.0307	11.7753	29.0756
logM	2,009	17.0900	1.9710	11.5129	27.6310
logL	2,009	2.0253	0.6964	1.3863	6.1225
log(K)2	2,009	328.7302	75.4065	138.6574	845.3896
log(M)2	2,009	295.9508	69.5978	132.5474	763.4733
log(L)2	2,009	4.5864	3.7332	1.9218	37.4849
log(KxM)	2,009	310.9871	68.0658	153.9373	725.6490
log(KxL)	2,009	37.2372	16.4230	16.9212	151.3095
log(MxL)	2,009	35.3454	15.6505	16.5224	136.7651
<i>Inefficiency model</i>					
Size	2,009	0.9771	0.1496	0	1
lnage	2,009	1.5310	0.9745	0.0000	4.0254
Edu_manager	2,009	0.0831	0.2761	0	1
Foreign_inv	2,009	0.0169	0.1290	0	1
Export	2,009	0.0333	0.1796	0	1
Account	2,009	0.2658	0.4419	0	1
Credit	2,009	0.2738	0.4460	0	1
IT	2,009	0.0737	0.2613	0	1
Sub1	2,009	0.3076	0.4616	0	1
Sub2	2,009	0.0946	0.2927	0	1
Sub3	2,009	0.0911	0.2878	0	1
Sub4	2,009	0.2877	0.4528	0	1
Sub5	2,009	0.2190	0.4137	0	1
Province1	2,009	0.2882	0.4530	0	1
Province2	2,009	0.0110	0.1041	0	1
Province3	2,009	0.0090	0.0943	0	1
Province4	2,009	0.0234	0.1512	0	1
Province5	2,009	0.0209	0.1431	0	1
Province6	2,009	0.0617	0.2407	0	1
Province7	2,009	0.0189	0.1363	0	1
Province8	2,009	0.0707	0.2564	0	1
Province9	2,009	0.0309	0.1730	0	1
Province10	2,009	0.0821	0.2746	0	1
Province11	2,009	0.0408	0.1979	0	1
Province12	2,009	0.0622	0.2416	0	1
Province13	2,009	0.1299	0.3363	0	1
Province14	2,009	0.0279	0.1647	0	1
Province15	2,009	0.0095	0.0968	0	1
Province16	2,009	0.0856	0.2799	0	1
Province17	2,009	0.0273	0.1632	0	1

Note(s): Note that Sub1 = food, beverage and tobacco; Sub2 = garment and textile; Sub3 = paper and printing; Sub4 = chemical and plastic; Sub5 = others including furniture, electronic, machine and vehicle. Province1 = Vientiane Capital, Province2 = Phongsaly, Province3 = Luangnamtha, Province4 = Oudomxay, Province5 = Bokeo, Province6 = Luangprabang, Province7 = Huaphanh, Province8 = Xayabury, Province9 = Xiengkhuang, Province10 = Vientiane, Province11 = Borikhamxay, Province12 = Khammuane, Province13 = Savannakhet, Province14 = Saravanh, Province15 = Sekong, Province16 = Champasack and Province17 = Attapue

Source(s): Economic Census Survey (ECS) 2012/13, Lao Statistics Bureau (LSB), Lao PDR

Table 1.
Statistics summary for
the economic census
survey (ECS) in
2012/13

value (γ) obtained lies between 0 and 1; and the closeness to 1 indicates that the frontier model was appropriated. After the statistical test, all models except Sub4 proved the existence of the technical inefficiency component with a significance at 1 and 5% meaning to reject the null

No	Log likelihood function	All sample	Sub1 (food, beverage)	Sub2 (garment, textile)	Sub3 (paper, printing)	Sub4 (chemical, plastic)	Sub5 (furniture, electronic, others)
1	Cobb–Douglas	–2731.10	–918.33	–224.56	–251.32	–717.85	–560.01
2	Translog	–2659.61	–891.96	–216.59	–237.51	–704.69	–539.30
3	LR-stat	142.97	52.73	15.93	27.60	26.32	41.42
4	Prob > χ^2	0.0000	0.0000	0.0141	0.0001	0.0002	0.0000
5	Decision	Rejected H0	Rejected H0	Rejected H0	Rejected H0	Rejected H0	Rejected H0
6	Appropriated model	Translog	Translog	Translog	Translog	Translog	Translog
7	No. of observations	2,009	618	190	183	578	440

Table 2. Log likelihood ratio test for selecting the functional form

hypothesis of no technical inefficiency. In other words, only the industries in Sub4, including chemical and plastic firms, perform under the full efficiency in production.

The results for the stochastic production frontier model illustrate the expected signs of coefficients for key production factors, such as capital, material and labor. In general, the results exhibit that the Lao manufacturing industry tends to be more dependent on the production factor of labor rather than the capital and material or intermediate input. With high coefficient values of labor inputs, industries like food, beverage, garment, textile, paper, furniture, and others in Sub1, Sub2, Sub3, and Sub5 are considered labor-intensive industries. This labor-intensive sector contributed enormously to the economic development in Laos, specifically contributing to job creation and export in the previous years. For instance, in the garment and textile industry, Laos had 85 garment factories altogether in 2016 [3], mainly located in the Vientiane Capital and Savannakhet province in the central region of the country. It created 27,000 jobs – dominated by female workers, composing 24.5% of the total employment in the manufacturing sector with its export being more than 140 million dollars – 13.4% of the total non-resource export (Bank of the Lao PDR, 2016). However, a majority of these laborers have fewer skills or basic education; more than 85% only attended primary and junior high school according to the database from the 2015 population census by LSB (2015b). On the other hand, the study from the Thailand Development Research Institute Foundation (2015, p. 63) revealed that the supply of skilled laborers in Laos is limited, while the existing local skilled employees exhibit subpar performance under the international standard due to their lack of sufficient knowledge and experience. Hence, firms prefer recruiting foreign-skilled workers in top positions including the chief executive, director, and management as well as for technical positions such as engineer, supervisor, and assistant manager. In contrast, the manufacturing firms of metal, electronics, machines and vehicles contain more capital-intensive production. Their rate of capital intensity is much higher, four times more than the aforementioned groups of industries, based on the ECS 2012/13. However, the electronic manufacturing of Laos is regarded a light industry and comparatively small, as it is engaged in the preliminary production of the regional production network, such as producing parts, components and assembled products supplied to the regional hubs, including Thailand, for further production assembly (Economic Research Institute for ASEAN and East Asia, 2016, p. 156). In general, the signs of key production factors indicate a positive implication if the firms desire to increase the output. However, the interaction between capital, material and labor negatively affects the production across firms which should indicate the inefficient use of combined inputs although the magnitude of the coefficient is relatively small. Yet, the negative sign of the labor

Table 3.
Estimates for
parameters of
stochastic production
frontier and technical
inefficiency

Variable	All sample	Sub1 (food, beverage)	Sub2 (garment, textile)	Sub3 (paper, printing)	Sub4 (chemical, plastic)	Sub5 (furniture, electronic, others)
<i>Stochastic production frontier model (dependent variable: logY)</i>						
Constant	-0.095***	-5.680*	4.147	0.336	-1.3114	2.854
logK	0.711***			0.858**	0.8715**	0.766**
logM	0.657***	1.469***			0.6245*	
logL	1.617***	2.337***	2.000***	2.628**		1.478**
log(K)2				0.046**		
log(M)2						
log(L)2	-0.056*	-0.028*		-0.056*		-0.167***
log(KxM)	-0.035***			0.133*	-0.066**	
log(KxL)				-0.304		
log(MxL)	-0.061**					
<i>Technical inefficiency model (dependent variable: logU)</i>						
Constant	1.5179	-2.1580	0.9166	1.1929		1.6683*
FirmSize	-0.7472*					
lnage						
Edu_manager				-0.9578*		
Foreign_own						
Export				-1.8559***		
Account	-0.2502*					
Credit	-0.7600***	-0.9849**	-1.0509**			-0.5638**
IT						
Sub1	1.1391***					
Sub2	1.0972***					
Sub3	0.6415**					
Sub4	0.4724**					
Province1	-1.304***	-2.2676**				
Province2				2.5082**		
Province9	-1.3441**					
Province10	-0.5161*					
Province11	-0.9537**					
						-1.7828*

(continued)

Variable	All sample	Sub1 (food, beverage)	Sub2 (garment, textile)	Sub3 (paper, printing)	Sub4 (chemical, plastic)	Sub5 (furniture, electronic, others)
Province15	-0.8691**	-2.1036**		3.8078*		
Province16	0.9658	0.9556	0.9421	0.9722	0.1110	0.9700
Gamma (γ)	-2570.00	-852.36	-200.87	-213.63	-704.69	-518.35
Log likelihood	0.7251	0.7149	0.5912	0.5440	1.0000	0.6471
Mean efficiency	0.0000	0.0380	0.0000	0.0010	0.7430	0.0000
H0: No inefficiency component						
(Prob > χ^2)						
Number of observations	2,009	618	190	183	578	440

Note(s): ***, ** and * denote significance at the 1, 5 and 10% level, respectively
 Note that the variables of location by province are not all reported, only the ones with a significant statistical test for all samples are displayed to save space

Table 3.

variable's square, especially in firms in the Sub5 group, indicates that these firms experienced a diminishing return to labor or there was an overuse of labor supply in the production.

Factors behind the technical inefficiency across firms in the survey are also reported in [Table 3](#) as the major interest of this study, where all the signs of the coefficients of variables except IT are expected. Since the dependent variable is the component of technical inefficiency, the sign of negative coefficients suggests that independent variables play an important role in reducing technical inefficiency and vice versa. In other words, the negative sign of the coefficient indicates more technical efficiency; therefore, it is desirable to detect negative coefficients in the result. The results share some similarities and differences with that of previous studies. For all samples, the difference is that the key firm's specific variables – the firm's age, foreign investment, export activity and education – are not significant statistically, causing the result to vary from previous studies in Thailand, Vietnam, Malaysia and Indonesia. Contrarily, the similar results are due to the effects of a firm's size along with the subindustry and location. Particularly, the impact of the firm's size is negative on technical inefficiency, indicating that small enterprises are more efficient than the larger ones because of their adaptability and flexibility of using or changing the production inputs according to the change of markets. [Charoenrat and Harvie \(2013, p. 385\)](#) received a similar outcome in the case of Thailand. The variables of the accounting system and credit access are statistically significant, returning an interesting result which differs from earlier studies, indicating that firms which apply the standardized accounting system for their management and have better access to financing are more efficient than those that do not engage in these activities by 25.02 and 76%, respectively. This is because the introduction of an accounting system guides the managers of the firms to take better, more informed decisions on the production operation and understand other potential influences on their business ([Fry et al., 1998](#)). On the other hand, credit access is crucial in reducing technical inefficiency by mitigating financial constraints and ensuring optimal inventory management ([Agostino and Trivieri, 2019, p. 589](#)). Moreover, [Giang et al. \(2019, p. 14\)](#) found that credit access had improved the productivity of SME manufacturers in Vietnam by 8–9%. The issues of financial accounting and credit access have been one of the major constraints for private firms in Laos for a long period since several enterprises, especially small and medium firms, operate a business without the use of a formal accounting system while suffering difficulties of credit access due to the restriction criteria – such as collaterals and feasible business plans – in commercial banks. The perception of managers from the World Bank's enterprise survey in 2012 confirmed that credit access was the biggest constraint for their business ([World Bank Group, 2018, p. 23](#)). Meanwhile, there are still plenty of manufacturing firms – more than 80% of the total – which did not implement an accounting system ([Lao Statistics Bureau, 2015a, p. 71](#)). Therefore, addressing these two major constraints could aid manufacturing firms in improving their production efficiency.

In subindustries, the impact of the accounting system on technical inefficiency is likely to be workable only for firms in Sub5 whereas the credit access is valid for the industries in both Sub1 and Sub2. This result might depict that the practice of maintaining an accounting system and the access to financing are major constraints specifically to firms in Sub5, Sub1 and Sub2. Similarly, the [World Bank Group \(2018, pp. 7–8\)](#) discovered several constraints across different types of firms from the enterprise survey. For instance, the education of the laborers is the major constraint for large firms, whereas poor transportation proves to be the most concerning for medium-sized and exporting firms, thereby verifying the specific constraints suffered across different groups of industries. Additionally, laborers' skills (educated manager) and export activity influence the reduction of technical inefficiency for paper and related printing firms in Sub3. This might be because this type of industry requires skilled laborers at managerial positions while operating under the pressure of high competition from international trade. Regarding the laborers' skills, higher-educated laborers

can help the company improve the use of existing technology as well as the absorption of new technology, which will consequently result in enhancing production efficiency (Charoenrat and Harvie, 2013; Mahadevan and Mansor, 2007; Zahid and Mokhtar, 2007). Likewise, firms which are involved with international trade are more efficient because the competition with foreign firms abroad forces them to improve the use of production resources in the most effective way (Vu, 2016). Nevertheless, there might exist a correlation between laborers' skills and trade activity since there is a study by Vilavong *et al.* (2016, p. 11) – which used the World Bank's enterprise surveys in 2009 and 2012 – finding that the education of managers is linked to the participation of regional production networks (trade). Fortunately, this study finds no correlation between educated managers and trade activity by examining their correlation value and the test of model modification.

As mentioned, the variable of foreign investment is insignificant along with the age of the firm on the inefficiency. Thus, foreign firms are indifferently efficient compared to domestic firms, as many foreign firms in the Lao People's Democratic Republic (PDR) are under subcontracts and spend less effort on R&D or innovation activities, possibly differing from the case of Thailand and Vietnam. A typical example is the garment industry where many foreign-invested garment firms are medium-sized with subcontract production or regarded merely as a production base that is heavily dependent on the number of low-skilled laborers. Therefore, labor shares account for more than half of the total production costs (Sthabandith *et al.*, 2010). The process of their production is simply categorized as cut-make-trim (CMT) for the orders overseas. CMT service is where Lao garment firms are under instruction and supervision from overseas intermediaries responsible for the purchase of fabric, financing, international logistics and delivery of the final product to the foreign purchasers. Therefore, foreign firms invest as little in R&D and human development as the domestic firms (Nolintha and Yee, 2015), leading to no differences in efficiency. This finding should encourage foreign investment firms or investors to contribute more to the enhancement of technical efficiency in Lao PDR. The variable of location effect, demonstrated for firms residing in province1, province9, province10, province11 and province16, are more efficient than firms in other locations, presenting a large gap among different locations, especially in infrastructure. Locations with poor infrastructure would increase the transport cost and time, resulting in a rise of inefficiency to firms and vice versa. As a land-locked country, Laos already suffers a disadvantage in geographic location, leading to higher costs of transport for its international trade compared to its neighbors. Moreover, only 15.4% of all road networks in Laos are paved, much lower than other ASEAN countries (ASEAN Secretariat, 2019), rendering it difficult for firms in Lao PDR to transport manufacturing goods to international markets, especially from locations with poor infrastructure.

Finally, the level of technical efficiency was estimated from the model for all samples and subindustries. Overall, the levels of technical efficiency vary across sampling firms and different groups of manufacturers. The mean of technical efficiency for the total sample was found to be 72.51% with a standard deviation of 0.5% which is slightly higher than the levels in Thailand (50–57%), Vietnam (50–71.2%), Malaysia (56.2%), and Indonesia (55.87%). However, this should not demonstrate that Lao manufacturers are more efficient than their peers because each study applied a different dataset across different times, definitions and a number of observations. Regarding the subindustries, the results divulge that Sub4, which largely includes chemical and plastic manufacturers, is the most efficient among all subindustries since the statistical test displays no existing technical inefficiency. Meanwhile, Sub1, comprising food, beverage and tobacco firms, is the second most efficient industry in production, the third being the industries in Sub5, including metal, electronic, machine, vehicle, furniture, and other manufacturers, and the fourth garment and textile industries in Sub2 with a 59.12% efficiency level. When compared to the study by Vixathep (2011), this level is higher which might be due to the use of different datasets. The variation in the levels

of technical efficiency in the subindustries confirms the evidence of heterogeneity, extant in the international literature. Such differences should be explained by differences in the firm's characteristics, technologies and location effects as already discussed in this section. For instance, credit access affects the level of technical efficiency in Sub1 and Sub2, whereas educated managers and trade activity do in Sub4.

To check the issue of multicollinearity or correlation among variables, this study conducted the correlation estimation and a test of modification of regression specification by adding or removing regressors in Table 4. First, it reported the correlation value among variables, presenting that the majority of values is low – less than 0.1 or 10% – whereas there are a few values above that level but still below 0.4 or 40%, thus indicating that the issue of multicollinearity is unlikely. On the other hand, another test of multicollinearity was carried out where the simultaneous estimations in one step were repeated for the modification test among variables. Note that the variables for the production model were not considered for the test since it was already examined by the likelihood ratio test under the hypothesis of the Cobb–Douglas functional form (reduced form) against the translog functional form (extended form). Additionally, the test was conducted for all samples; however, it did not include all the subindustries in order to save space. Consequently, 12 sub-models were obtained in total, as shown in Table 5, resulting in the signs of interested variables remaining unchanged with the exception of IT, its sign turning from a negative to a positive when a variable of Sub1 was added into the model – implying that IT and Sub1 are closely correlated. To deal with this issue, one of these two variables should be dropped out from the model. For the remaining variables, the signs of their coefficients remained unchanged throughout models 1 to 12 although the magnitudes of some significance levels were slightly affected. Overall, the signs and statistical tests for most of the interested variables remained unchanged. Thus, based on the test of model modification and correlation value, it is sufficient to conclude that the econometric results for the technical inefficiency model in Table 3 are fairly plausible for policy implication.

5. Conclusions

Laos is one of the few developing Asian countries with a high recorded economic growth over the last two decades. However, its growth is heavily weighed down by physical capital, mainly from the resource sector. As a result, the labor productivity of the resource sector is extremely high, distorting the measurement of national labor productivity as well as the income per capita. Under this resource-led growth, the Lao economy is unsustainable in terms of the income distribution, limited stock of resources and easy exposure to external shocks such as varying commodity prices. Therefore, it presents a huge challenge for Laos to sustain economic growth in the future and achieve the government's development target by 2030. Developing the manufacturing industry through productivity is an alternative option to sustain the economic growth, income level and income distribution. Currently, the knowledge and understanding of the Lao manufacturing industry, especially the technical efficiency of production as a component of productivity at the firm level, are limited since only a few studies have been implemented thus far. Therefore, this study sought to add value to the existing literature by investigating the technical efficiency of Lao manufacturing firms by using cross-sectional data from the ECS in 2012/13 and SFA.

The study found that the efficiency level varied across subindustries with an average of 72.51% in frontier or full potential production, which is relatively higher than its regional peers. Out of the five classified groups, Sub4 (chemical and plastic) was found to be the most efficient manufacturer, while the rest in order are Sub1 (food and beverage), Sub5 (furniture and others), Sub2 (garment and textile), and Sub3 (paper and printing), providing the evidence to improve the technical efficiency, especially for the firms in Sub3 and Sub2 groups.

Variable	FirmSize	Inage	Edu_manager	Foreign_own	Export	Account	Credit	IT	Sub1	Sub2	Sub3	Sub4	Sub5
FirmSize	1.000												
Inage	-0.003	1.000											
Edu_manager	-0.120	-0.060	1.000										
Foreign_own	-0.159	-0.036	0.171	1.000									
Export	-0.175	0.028	0.076	0.132	1.000								
Account	-0.158	-0.019	0.163	0.205	0.218	1.000							
Credit	-0.011	0.063	-0.035	-0.018	-0.015	0.055	1.000						
IT	-0.242	0.026	0.251	0.259	0.124	0.288	0.073	1.000					
Sub1	0.068	0.060	-0.017	-0.097	-0.081	-0.046	0.003	-0.073	1.000				
Sub2	-0.082	-0.022	0.034	-0.045	-0.062	-0.058	0.002	0.042	-0.192	1.000			
Sub3	-0.133	0.001	0.103	0.067	0.271	0.218	-0.040	0.160	-0.211	-0.118	1.000		
Sub4	0.084	-0.098	-0.034	0.044	-0.091	-0.041	-0.013	-0.047	-0.384	-0.215	-0.236	1.000	
Sub5	-0.013	0.052	0.050	0.065	-0.018	0.035	-0.009	0.061	-0.135	-0.076	-0.083	-0.151	1.000

Table 4.
Correlation value

Table 5.
Test for modification of
the technical
inefficiency model

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CONS	6.213***	6.173**	6.093***	5.766***	5.196***	5.298	4.847***	4.836***
FirmSize	-0.159	-0.159	-0.186	-0.191	-0.272	-0.329	-0.428*	-0.446*
lnage		-0.046	-0.048	-0.049	-0.048	-0.047	-0.041	-0.041
Edu_manager			-0.143	-0.129	-0.128	-0.105	-0.127	-0.122
Foreign_own				-0.398	-0.364	-0.326	-0.390	-0.385
Export					-0.743**	-0.691*	-0.903*	-0.911*
Account						-0.168*	-0.147*	-0.143
Credit							-0.413***	-0.412***
IT								-0.042
Log likelihood	-2659.4	-2658.5	-2657.9	-2657.2	-2653.5	-2651.5	-2640.3	-2640.3
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. Observation	2,009	2,009	2,009	2,009	2,009	2,009	2,009	2,009

Note(s): ***, ** and * denote significance at the 1, 5 and 10% level, respectively
Note that, to save the space, the variables of subindustry and province are not reported in the table

After controlling the location and subindustry effect, this study discovered that the firm's size, accounting system and credit access are crucial to enhancing the production efficiency of all sampling firms. However, these factors might be subject to specific industries. For instance, the education of the manager and trade-related activity is effective for production efficiency in paper and related printing manufacturers or firms in Sub3, whereas credit access holds the same value for food, beverage, garment and textile firms in Sub1 and Sub2. Similarly, the use of accounting systems in management is relevant for furniture and other manufacturing firms in Sub5. In order to elevate the efficiency level, the concentration should be subjected to specific industries and their unique needs. For instance, to improve the production efficiency of firms in Sub1 and Sub2, the easing of credit access is the most significant. Likewise, for firms in Sub5, the use of accounting systems in management is instrumental to progress their technical efficiency; and firms in Sub3 can upgrade their production efficiency by improving the education of their managers and engaging more with international trade. Nevertheless, the results from a subindustry could prove to be lessons for firms in another subindustry. For the implication to the business community and policymakers, the findings of this study could be a reference in terms of which areas they should concentrate on to improve the technical efficiency as a part of productivity in the manufacturing industry.

Finally, for further research, the analysis of technical efficiency must be updated regularly because the data used for the current study were from the 2012/13 period. Updated or enhanced data such as panel data would provide more robust analysis and understanding of the manufacturing sector's productivity and its components including technical efficiency in the current situation in addition to establishing plausible policy recommendations. More importantly, the analysis should include additional relevant policy variables related to skilled labor, training, governmental assistance and the business climate to make the implications more substantial.

Notes

1. The survey, which was conducted in 2018, covered 213 manufacturing firms that employed at least 25 employees in seven major commercial provinces.
2. The number of manufacturing firms in Thailand and Vietnam was extremely high with 424,196 firms in 2011 and 906,162 firms in 2017, respectively although the majority was micro- and small-sized enterprise (Thailand National Statistics Office, 2012; Vietnam General Statistics Office, 2018).
3. <https://www.nationthailand.com/news/30310392>

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