APPLICATION OF DEA AND SFA MODELS TO ASSESS THE TECHNICAL EFFICIENCY OF MANUFACTURING INDUSTRIAL ENTERPRISES IN VIETNAM IN THE PERIOD OF COVID 19

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The manufacturing industry is one of the main drivers of Vietnam's economic growth in general and industrial development in particular. The importance of the manufacturing industry poses an urgent requirement that is to quantify and evaluate the level of technical efficiency of enterprises. Data envelopment analysis (DEA) and Stochastic Frontier Analysis
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(SFA) are the two main methods used in assessing the technical efficiency of manufacturing enterprises in Vietnam. The article focuses on the application of DEA and SFA to assess the technical efficiency of manufacturing enterprises in Vietnam during the Covid epidemic. Besides, proposing solutions to improve the technical efficiency of manufacturing industrial enterprises in Vietnam.

**Keywords:** enterprises; manufacturing industry; technical efficiency; Data envelopment analysis (DEA) and Stochastic Frontier Analysis (SFA); Vietnam

**Introduction**

Vietnam is a rapidly developing country in the Asia region with the main growth driver coming from industry (Guzikova & Van, 2019). Notably, the manufacturing industry is growing sustainably and is a major contributor to the growth of the entire industry in this country (Lo Thi & Guzikova, 2020).

According to the General Statistics Office (2023), in 2020, the number of enterprises in the manufacturing industry group is 109.9 thousand, and owns 49.9% of the total number of employees in enterprises in Vietnam. The importance of the manufacturing industry requires the necessity to assess the level of technical efficiency (TE) of these enterprises.

The evaluation process needs to be quantified to be able to accurately analyze the technical efficiency of each enterprise as well as to allow comparison of operability between enterprises in the same industry. Assessing the technical efficiency of enterprises allows businesses and policy makers in Vietnam to understand the current situation, find inefficiencies that need to be improved, and identify the future goals.

Data envelopment analysis (DEA) and Stochastic Frontier Analysis (SFA) methods are highly regarded by many economists in assessing the technical efficiency enterprises (Wanke, 2020; Igorevic, 2021; Zhao, 2022).

Currently, there are not many studies in Vietnam focusing on the level of technical efficiency of manufacturing enterprises, especially with the above approach (Nguyen & Pham, 2020).

Therefore, this study focuses on solving the following main problems:
- measuring the level of technical efficiency of manufacturing industry enterprises in Vietnam.
- indicate the factors affecting the level of technical efficiency of manufacturing industry enterprises in Vietnam.
- proposing solutions to improve the technical efficiency of manufacturing industry enterprises in Vietnam.


Subject of research: enterprises in the manufacturing industries in Vietnam; number of surveyed enterprises: 280 enterprises; field of investigation: manufacturing industry; survey type: Joint Stock Company.

Research methods

Data collection method: Research, collect and use secondary data aggregated from public financial statements of enterprises in the industry on Vietstock Finance stock exchange in the period of 2019 - 2021.

Data analysis and processing:
+ Descriptive statistics
+ Comparative statistics
+ Multivariate statistics

Research model: the study uses data envelopment analysis (DEA) and Stochastic Frontier Analysis (SFA) to process data, test hypotheses and give conclusions.

Results

1. Systematize the theoretical basis of technical efficiency of the manufacturing enterprises in Vietnam and research model SFA, DEA.

Technical efficiency is the ability to increase output while keeping input constant (Deprins & Simar, 1983). Technical efficiency shows how much of a fixed amount of output using the least amount of inputs a firm can produce.

According to Vincová (2005), technical efficiency can be measured by methods such as SFA - Stochastic frontier analysis method, DFA - Detrended Fluctuation Analysis.

According to Thanassoulis (2001), the DEA model is a method to measure comparative or relative performance. DEA cannot be taken as a measure of absolute efficiency unless the additional assumption is made that the units being compared include an adequate number of absolute efficiency units.

According to Ramanathan (2003), DEA was introduced with the role of assessing the effectiveness of decision-making unit (DMU) resource use by building production possibility frontier (PPF).

Cooper (2011) argue that data envelop analysis DEA is a data-driven approach to evaluate the performance of a set of peer entities known as decision-making units (DMUs), which convert inputs to multiple outputs.

Meanwhile, Stochastic Frontier Analysis (SFA) is a method that uses econometric tools to determine the parameters of the production frontier. In which, the decision-making unit (DMU) inefficiency is considered as a non-negative random variable (Coelli & Rao, 2005).

2. Factors affecting the technical efficiency of manufacturing enterprises.

There have been many research studies on the technical efficiency of enterprises. Most studies, such as Ahmed & Wang (2012) or Kim Anh et al. (2020) all agree that there are at least 2 factors affecting the technical efficiency of manufacturing enterprises: capital (K) and labor (L)[14,15]. In addition, each study also provides a number of individual factors that the authors believe that these factors also affect the technical efficiency of enterprises. The research team summarizes and proposes a list of factors affecting the technical efficiency of processing and manufacturing enterprises in Vietnam as follows:

- Capital: Capital can be measured by the value of the current working capital or by the sum of the current working assets of the business (Ahmed & Wang, 2012). Capital is one of
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the basic means of production units. In all studies, the reference group said that capital affects the technical efficiency of the enterprise.

2. Labor: Labor can be measured by the number of workers, average labor productivity or the amount paid to workers.

3. Administrative costs: administrative costs are expenses that enterprises must pay to maintain the operation of their production activities. Depending on the business, the calculation of administrative costs will also be different. Vu (2015) argues that administrative costs have an impact on the technical efficiency of enterprises.

4. Total assets: Total assets are all the resources that the enterprise is controlling and holding, the enterprise can obtain future benefits through the use of these assets.

5. Capital structure: also known as economic leverage. Capital structure is calculated by the formula: (Total assets – Owner's Equity)/Total assets. Using a reasonable and correct capital structure will increase the technical efficiency of the enterprise.

6. Selling expenses: Selling expenses are the sum of many different expenses incurred to sell goods in the business's market.

7. ROS: ROS is also known as return on sales. The ROS index shows how much profit after tax a business earns per dollar of sales.

8. ROE: ROE is also known as return on owner’s equity. ROE shows the efficiency of using capital of businesses, when they spend 1 dong of capital, how much profit will be earned.

9. ROA: ROA is also known as return on assets. ROA shows how much profit a business can generate with a given amount of existing assets.

10. Management ratio: Calculated by the formula: (Administration cost/Revenue). Accurately calculated ratios will greatly assist businesses in making important decisions for more developed business.

11. Sales ratio: This indicator is calculated according to the formula: Selling expenses/Net revenue. The smaller this indicator, the higher the technical efficiency, and the more beneficial it is for the business.

12. Enterprise age: Enterprise age is measured by the number of years the business has been in operation since the date of establishment. In studies, firm age is often directly proportional to technical efficiency, showing that established firms have certain advantages over startups.

13. Manufacturing sector: The manufacturing sector of the firm is measured by dummy variables.

14. Region: The regional factor of an enterprise is measured by dummy variables (1: North, 2: South, 3: Central).

15. Gender: Business owner gender as measured by dummy variable (1: Male, 0: Female). Gender also has a certain influence on the technical efficiency of enterprises. According to Ndoro (2012), when the business owner is male, the business will often operate more efficiently, thanks to the advantages of men in the business process.

16. Education level of business owners: Education level of business owners is measured by dummy variables (6: Undergraduate and graduate, 5: College, 4: Intermediate, 3: Elementary, 2: Training less than 3 months and 1: Not trained).

17. Since businesses are investigated on the stock exchange, the stock exchange is measured by dummy variables (1: OTC, 2: UpCOM, 3: HNX và 4: HOSE)
18. Covid impact: The topic explores the technical efficiency of enterprises during the Covid-19 period, so the Covid impact variable is measured according to dummy variables (0: before Covid; 1: during Covid).

19. Popularity: The popularity of the manufacturing sector is measured through dummy variables (1: low popularity, 2: moderate popularity, 3: high popularity).

This study will use two models. The first model is a revenue function to calculate technical efficiency, with the dependent variable representing the outputs and the independent variable representing the inputs. This model will take the form:

$$\ln DT = \beta_0 + \beta_1 \ln LD + \beta_2 \ln NV + \beta_3 \ln QL + \beta_4 \ln TS + \beta_5 \ln BH + \varepsilon \quad (1)$$

Where:
- $\ln DT$: The independent variable is the natural logarithm of net revenue
- $\ln LD$: Natural logarithm of labor cost
- $\ln NV$: Natural logarithm of owner’s equity
- $\ln QL$: Natural logarithm of administrative costs
- $\ln TS$: Natural logarithm of total assets
- $\ln BH$: Natural logarithm of cost of goods sold
- $\beta_0$: Constant
- $\beta_i$: Overall regression coefficient corresponding to the independent variables, $i=1, 2, \ldots, 5$
- $\varepsilon$: Remainder

The second model is the model used to test the factors affecting technical efficiency. Based on the results of previous studies, the research model of factors affecting technical efficiency is expected as follows:

$$TE = \gamma_0 + \gamma_1 tuoi + \gamma_2 vungmien + \gamma_3 gioitinh + \gamma_4 trinhdohocvan + \gamma_5 cautrucvon + \gamma_6 lnROS + \gamma_7 lnROE + \gamma_8 lnROA + \gamma_9 tuyuatQL + \gamma_10 tuyuatBH + \gamma_11 sanCK + \gamma_12 TdCovid + \gamma_13 mucphobien + \omega \quad (2)$$

In there:
- $TE$: The dependent variable in the model is the technical efficiency of the enterprise.
- $tuoi$: Enterprise age
- $vungmien$: Region
- $gioitinh$: Gender of the business owner
- $trinhdohocvan$: Education level of the business owner
- $cautrucvon$: The capital structure of the business
- $lnROS$: Natural logarithm of enterprise’s ROS
- $lnROE$: Natural logarithm of enterprise’s ROE
- $lnROA$: Natural logarithm of enterprise’s ROA
- $tuyuatQL$: Management ratio of the enterprise
- $tuyuatBH$: Sales ratio
- $sanCK$: Registered enterprise stock exchange
- $TdCovid$: Impact of Covid on businesses
- $mucphobien$: Popularity of the enterprise’s production field
- $\gamma_0$: Constant
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- $\gamma_i$: Overall regression coefficient corresponding to the independent variables, $i=1, 2, ..., 13$
- $\omega$: Remainder

Sampling method: Green (2003) proposed the formula to determine the sample size as $n > 50 + 8p$ (where $p$ is the independent variable in the model). With this topic, the research team systematizes the studies and inherits the relevant previous studies, combines with the actual conditions, adjusts to build the research model and finally put it into the research model.

Research proposal of the topic with 13 independent variables.

Therefore, the required sample size for this study is $n > 50 + 8*13 = 154$. Therefore, the research team selected the sample size of 277 processing and manufacturing enterprises operating in Vietnam. Vietnam has been listed on the stock exchange Vietstock Finance.

With a sample size of 277 enterprises, the research team ensures that the expected sample size has the necessary reliability for the study.

Results of technical efficiency by production field of enterprises in the manufacturing industry

The results of technical efficiency assessment of manufacturing enterprises in Vietnam in the period of 2019-2021 are shown in Tab. 1 and 2.

Table 1 - Technical efficiency by production field of listed manufacturing enterprises (Source: Calculation from survey data 2021)

<table>
<thead>
<tr>
<th>The production field</th>
<th>TE in DEA</th>
<th>TE in SFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food production and processing</td>
<td>0.815</td>
<td>0.834</td>
</tr>
<tr>
<td>Beverage production</td>
<td>0.967</td>
<td>0.92</td>
</tr>
<tr>
<td>Tobacco production</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Textile</td>
<td>0.935</td>
<td>0.943</td>
</tr>
<tr>
<td>Garment</td>
<td>0.955</td>
<td>0.921</td>
</tr>
<tr>
<td>Wood processing and wood products, bamboo, straw, straw and plaiting materials</td>
<td>0.998</td>
<td>1</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td>0.976</td>
<td>0.988</td>
</tr>
<tr>
<td>Producing coke, refined petroleum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>0.581</td>
<td>0.613</td>
</tr>
<tr>
<td>Production field</td>
<td>TE in DEA</td>
<td>TE in SFA</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Producing drugs, pharmaceutical chemicals, pharmaceutical materials</td>
<td>0.963</td>
<td>0.932</td>
</tr>
<tr>
<td>Producing products from rubber and plastic</td>
<td>0.918</td>
<td>0.886</td>
</tr>
<tr>
<td>Manufacture of other non-metallic mineral products</td>
<td>0.864</td>
<td>0.859</td>
</tr>
<tr>
<td>Manufacture of prefabricated metal products</td>
<td>0.859</td>
<td>0.842</td>
</tr>
<tr>
<td>Manufacture of electronic products, computers and optical products</td>
<td>0.96</td>
<td>0.966</td>
</tr>
<tr>
<td>Manufacture of electrical equipment</td>
<td>0.874</td>
<td>0.884</td>
</tr>
<tr>
<td>Manufacture of machinery and equipment not classified elsewhere</td>
<td>0.858</td>
<td>0.914</td>
</tr>
<tr>
<td>Manufacture of other means of transport</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Manufacture of beds, cabinets, tables and chairs</td>
<td>0.906</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Net revenue by production sector of listed manufacturing enterprises
(Source: Calculation from survey data 2021)

<table>
<thead>
<tr>
<th>Production field</th>
<th>Net revenue(billion Vietnamese Dong)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2019</td>
</tr>
<tr>
<td>Food production and processing</td>
<td>4969,813</td>
</tr>
<tr>
<td>Beverage production</td>
<td>3621,216</td>
</tr>
<tr>
<td>Tobacco production</td>
<td>690,849</td>
</tr>
<tr>
<td>Textile</td>
<td>1725,695</td>
</tr>
<tr>
<td>Garment</td>
<td>3673,119</td>
</tr>
<tr>
<td>Wood processing and wood products, bamboo, straw, straw and plaiting materials</td>
<td>1484,108</td>
</tr>
</tbody>
</table>
From Table 1 and Table 2, the following results are obtained:

In terms of net revenue, from 2019 to 2020 there is a heterogeneous change between different manufacturing sectors when 11 manufacturing sectors have a decrease in average net revenue and 10 manufacturing sectors have average net sales increased.

By 2021, there will be a more uniform change when 85% of the manufacturing sector has a decrease in net revenue, only 3 areas with an increase in net revenue are: food production and processing; producing coke, refined petroleum; Manufacture of prefabricated metal products. For the food production and processing industry, the reason may be that this is an industry with a relatively high demand when food is one of the most essential commodities; consumption demand is stable even during the Covid-19 period.

The other two sectors producing coke, refined petroleum and manufacturing prefabricated metal products are two manufacturing sectors that are also less affected by the Covid-19 pandemic when the supply chains of these two industries are less disrupted.
by the Covid-19 pandemic, and the demand for products of these two fields has not been cut during the pandemic.

Regarding technical efficiency, almost all fields have TE calculated according to SFA that varies according to a certain rule. TE calculated by SFA of all sectors will increase slightly or unchanged in 2020 and decrease in 2021. This indicates that the majority of manufacturing enterprises will have to spend more to do business in 2021, further reinforcing the hypothesis as outlined in the industry-wide TE analysis, that enterprises Businesses in 2021 have had to make other investments for a new way of doing business to adapt during the pandemic. TE calculated by DEA is significantly different from TE calculated by SFA. However, in production fields with many enterprises, such as food production and processing, chemical production, production of non-metallic mineral products, etc., the TE results measured by DEA are quite similar with TE due to SFA because the number of enterprises to build the linear programming problem is large enough.

Therefore, it can be confirmed that TE measured by SFA has high accuracy and is of reference value for research.

Through the results of the technical efficiency of processing and manufacturing enterprises in Vietnam during the Covid-19 period, the average revenue from 2019 to 2020 tends to decrease. From 2020 to 2021, the revenue tends to increase. This can explain the fluctuations in production and business activities of manufacturing enterprises during the Covid-19 epidemic, but from those fluctuations, there are bright spots, opportunities, and new directions are opened. The difficulties and challenges also force businesses to change the way of production and operation to adapt to the general situation of the market.

During the survey and research, the research paper has shown the steady growth of the food manufacturing and processing industry. This is an industry with relatively high and stable demand even during the Covid-19 epidemic and is the industry that accounts for the highest proportion in the processing and manufacturing industries, demonstrating the industry's importance in ensure the food needs of the people as well as meet the export requirements.

Therefore, the epidemic is at the same time a challenge but also a good opportunity to help Vietnam's foods reach new markets such as promoting activities on the electronic floor, doing business online. The food production and processing industry has a strong advantage, which is reflected in its high production proportion. This is also an industry with advantages of prestige, stable market and high competitiveness compared to foreign enterprises.

In industries such as production and processing of milk, beverages, cooking oil, and confectionery are forecasted to have high growth trends and have the potential to become dynamic market sectors. In addition, due to its great potential, Vietnam's food manufacturing and processing industry is very attractive to foreign investors. In the past years, there have been many M&A deals in the food industry (mergers and acquisitions of food processing companies) taking place and this trend is expected to continue in the coming years.

The results show that most manufacturing enterprises in Vietnam are large-scale enterprises, with only a few medium-sized enterprises. Covid-19 has progressed for a very long time, with no tendency to stop.

This makes it difficult for businesses, especially medium-sized ones. Insufficient resources, difficulties in production and business due to infected workers, or isolation, etc. are all obstacles for businesses to adapt to the situation at that time.
Most of the manufacturing enterprises in Vietnam have not focused on investing in technology science (in production equipment, raw materials and in the production - business process according to foreign standards). Therefore, the products of Vietnam that are brought to the international market are often not appreciated by other countries.

In addition, due to the worldwide outbreak of the Covid-19 pandemic, the global supply chain was interrupted, causing serious impacts on import and export activities of countries around the world, including Vietnam.

**Solutions to improve technical efficiency for manufacturing enterprises in Vietnam during the Covid-19 period**

For Vietnam's manufacturing enterprises, the following group of solutions is proposed: managing businesses more effectively through technological solutions; mobilize, accumulate and use capital efficiently and reasonably in order to establish an appropriate capital structure for the enterprise; streamlining the management system and rationalizing the corporate governance apparatus.

For the State and authorities at all levels and localities in Vietnam, it is proposed to synchronously implement solutions: support investment, develop young businesses, start-up businesses; training and developing high-quality human resources; building a legal corridor and a healthy and fair competition environment for businesses.

**Conclusion**

The present study has shown the factors affecting the technical efficiency of manufacturing enterprises in Vietnam during the Covid-19 period. Through the research results, the technical efficiency of these enterprises in the period of 2019 - 2021 tended to increase in 2020, the trend decreased gradually in 2021. Since then, the study proposes a number of solutions in order to improve technical efficiency for processing and manufacturing enterprises in Vietnam during the Covid-19 period.

This research is the premise for further research and development in understanding the technical efficiency of enterprises in the manufacturing industry. Based on that, measures that can be applied to enterprises in the manufacturing industries in different regions in order to achieve the best technical efficiency have been proposed. The research results can be used as an assessment method to complete the development strategy of Vietnam's processing and manufacturing industry in particular and the industrial development strategy in general for the period up to 2030 with a view to 2050.

**References:**


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