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Efficiency of the Automotive Industry in the Visegrad Group

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Abstract: This article assesses the production efficiency of automotive sector companies in the V4 countries. The automotive sector has undergone dramatic changes in recent years, and its future development is still unclear. The assessment of company efficiency thus represents an important tool that could support decision-making on the future of this sector. Unfortunately, comprehensive studies based on micro-data on companies are not yet available. This article evaluates production (technical) efficiency based on accounting data of individual companies in the V4 countries using the parametric method of stochastic frontier analysis. In these analyses, efficiency is examined not only from the point of view of a country but also with respect to the size of a company. The empirical results show that not only country but also the size of a company are factors that have a statistically significant effect on company efficiency. Small companies struggle to keep up with their competitor and in general have the lowest efficiency ratings.

Keywords: Automotive, company, efficiency, stochastic frontier analysis

1. Introduction

The automotive sector is currently a significant part of the European economy. In some countries, it is even the most important sector, generating the bulk of the country's gross domestic product and providing thousands of jobs. The importance of the automotive industry is especially evident in Germany, France, and the United Kingdom where it has significant historical roots. In one sense, the Czech Republic can be included with these countries. Other countries that do not have such strong historical ties to vehicle production have begun to focus strongly on this sector in the last few decades, for a number of reasons, including e.g., the inflow of foreign investment, jobs growth etc.

It should not be forgotten that the actual production of vehicles requires a very wide network of suppliers and thus increases business opportunities in the area. The importance of this sector for the European Union is reflected in the statement of the European Commission [1], according to which it a key point of European prosperity.

It is thus clear that for such an important sector, it makes sense to ask how the economic resources that go into it are used. Several authors have already asked this question, but most of them do not deal with the European market but with the Asian or North American market, for example. In this context, there can be mentioned e.g., the work of Fei and Li [2], who deal with a similar issue in the Chinese automotive sector. Among other things, they found that state-owned companies are less efficient than private companies. Stefanoni and Voltes-Dorta [3] evaluated the efficiency of companies in the automotive sector from a global perspective. Their results point to higher efficiency of European producers compared to Asian and American competitors. From local research there can be mentioned Papoušková et al. [4], who deal with the issue of automotive industry efficiency in the Czech Republic. An overview of individual studies on a given topic is shown in Table 1.

Table 1 An overview of individual studies. Source: [2-15]

Authors	Period	Dataset
Shaobing and Xixian (1996) [5]	1971–1993	1 Chinese automaker
Xie and Wang (2009) [6]	1997–2005	11 Chinese automakers
Nandy (2011) [7]	2007–2008	Indian automakers
Maritz and Shieh (2013) [8]	2007–2009	6 Taiwanese automakers
Guan and Pan (2014) [9]	2012	26 Chinese automakers
Çalmaşur (2016) [10]	1992–2012	20 Turkish automakers
Otani and Yamada (2017) [11]	2008–2012	8 Global automakers
Choi et. al. (2017) [12]	2005–2012	16 Global automakers
Du et. al. (2018) [13]	2005–2012	3 Chinese automakers
Fei and Li (2018) [2]	2008–2013	28 Chinese automakers
Jiang et. al. (2018) [14]	2012–2016	77 Chinese automakers
Panigrahi (2019) [15]	2008–2018	19 Indian automakers
Papouskova et. al. (2020) [4]	2018	5 Czech and German automakers
Stefanoni et. al. (2021) [3]	2014–2017	33 Global automakers

Most of the published studies deal with the automotive industry in China. However, there are still not many studies that focus on this sector in the European region, specifically the V4 countries. Furthermore, many studies work with the data from the period of the 2008 financial crisis.

Therefore, there can be assumed an increased interest in assessing the efficiency of the use of economic resources during economic recession. At this point, there shall be mentioned the pandemic-related crisis that broke out at the beginning of 2020 and significantly paralyzed the entire sector. This is evidenced by a recent statement by Deloitte [16], which points to the withdrawal of producers from unprofitable markets and the consequent decline in production. In addition, there was a significant redirection of capital flows, especially into science and research. It is thus appropriate to compare the changes in efficiency that have taken place and whether these changes differ from country to country. Data from Statista [17] show that the automotive sector in the European Union is the most affected one by the coronavirus crisis. In terms of the V4 countries, it can be seen that the Czech Republic has been hit hardest.

Finally, it should be stated that the automotive sector in Europe is currently at a crossroads, and it is not certain whether it will move towards full electrification or whether conventional vehicle types will persist for some time [18]. While electric vehicles are likely to significantly transform the automotive industry and cause some sectors to disappear, they will also open the door to new technologies and force existing sectors to innovate, for example, in terms of building charging infrastructure and reducing overall emissions in vehicle production and operation [19]. Moving to a higher level of electrification requires a significant change in production and the technologies used, and it would be interesting to compare these types of production. The issue of automotive sector transformation is also addressed by KPMG [20], who conclude that by 2030, a maximum of 5% of global car production will be located in Western Europe, compared to the current 15%. According to other predictions, by 2040, electric cars will make up about one third of all cars produced. There are also differences in the policies of individual countries in the field of the automotive industry, with those in the United States and China being described clearer than in the European Union.

The next step within the automotive sector is the concept of autonomous driving, which is currently associated predominantly with electric cars. According to a survey conducted by [21] concerning the adoption of autonomous vehicles in Poland, it appears that people are ready for this type of vehicle, and it is only a matter of time and technology development before it reaches the market on a larger scale. As for the V4 countries, a significant increase in alternative vehicle types, for example in Poland where attention is currently being paid also to building the charging infrastructure [22]. The automotive industry also faces the problem of high prices of EV compared to conventional cars. The problem is the high cost of research and development of new EV technologies and their low popularity [23].

It follows from the above that the European Union is experiencing dramatic changes and the future of the automotive sector is unclear. Since the V4 countries represent a significant part of the automotive sector network, it shall be determined what efficiency these countries achieve in this

sector. For this reason, companies based in the V4 countries were selected and their efficiency was examined based on their parameters. The main objective of this article is to evaluate the efficiency of companies operating in automotive in the V4 countries. Thanks to microdata available, it is possible to analyze their efficiency not only in terms of the geographical area they operate in, but also with respect to their size. The sub-goal is thus to find out whether companies of different sizes show significantly different results in terms of their efficiency.

2. Data and Methods

Accounting data (annual frequency) on individual companies were obtained from the Orbis (Bureau van Dijk) database. The analyzes are based on data from 2015 to 2019, as most companies did not provide information on their sales for 2020. In total, information from 834 companies was obtained (see Table 2).

Table 2 Number of companies in individual countries (according to company size). Source: authors

Country	Number of companies (size of company)	Total number
Czech Rep.	8 (small), 31 (medium), 42 (large), 50 (very large)	131
Hungary	121 (small), 89 (medium), 60 (large), 32 (very large)	302
Poland	28 (small), 96 (medium), 97 (large), 39 (very large)	260
Slovakia	31 (small), 32 (medium), 56 (large), 22 (very large)	141

The efficiency of the companies was estimated using the parametric stochastic frontier analysis (SFA) (production possibility frontier). Unlike other methods, this method enables differentiating between inefficiency and noise [24]. It is possible to evaluate production (also referred to as technical) efficiency through estimating the production possibility frontier and thus evaluate the efficiency level of each company. Due to the nature of the data obtained, a two-factor Cobb-Douglas production function was chosen as in [24]. The production of companies is characterized by sales. The labor factor represents the variable cost of employees, which, as opposed to the mere number of employees, can also capture the different wage conditions in individual countries. In this article, the capital factor is expressed in its tangible form and is thus described in accounting terms as the total assets of the company. An overview of recent efficiency studies (from various sectors including the automotive industry) that used the same variables is presented in Table 3.

Due to the criticism that SFA estimation of efficiency can lead to inconsistent parameter estimates, a panel model according to [25] will be used to minimize the problem. To distinguish between fixed and random effects in the panel model, the Hausman test will be used as in [10]. In the case of the SFA method, it is also necessary to decide on the assumption of the inefficiency probability distribution and the type of estimator chosen. To ensure the robustness of the results,

estimates will be made on the basis of the two most commonly used probability distributions (specifically, exponential and half-normal) as well as through two efficiency estimates, an estimate based on the conditional mean of inefficiency according to [26] and, on the conditional mean of efficiency according to [27]. Correlation coefficients (Spearman and Pearson) will be used to determine the consistency between the obtained efficiency estimates as in [28]. SFA models were estimated by means of the STATA computing system (version 15) using functions implemented in [29].

Table 3 An overview of used variables including references to the studies in which they were used. Source: [2-7, 9-13, 15]

Factor	Accounting variable	Source
Output	Sales	Stefanoni et. al. (2021) [3], Papouskova et. al. (2020) [4], Panigrahi (2019) [15], Otani and Yamada (2017) [11], Choi et. al. (2017) [12], Çalmaşur (2016) [10], Shaobing and Xixian (1996) [5].
Labour	Cost of employees	Çalmaşur (2016) [10], Nandy (2011) [7].
Capital	Total assets	Stefanoni et. al. (2021) [3], Du et. al. (2018) [13], Fei and Li (2018) [2], Choi et. al. (2017) [12], Guan and Pan (2014) [9], Xie and Wang (2009) [6].

To analyze the efficiency results in terms of the size of the company as well as the country it operates in, analysis of variance will be applied to the resulting efficiency estimates. Since (in)efficiency will have one of the above probability distributions, it is not possible to apply a parametric method; therefore, a non-parametric Kruskal-Wallis analysis as in [30] will be used. The Kruskal-Wallis test will be supplemented by the Wilcoxon test to identify statistically different pairs as in [31]. This analysis will be performed using the R programing language, version 4.1.2.

3. Results

In the first step, it is necessary to select a suitable model for estimating efficiency. Based on the very low p-value of the Hausman test (<0.001), the null hypothesis is rejected, and a panel model is chosen with fixed effects instead of the random ones. Four efficiency estimates were obtained in total, i.e., a model estimate was compiled for each type of probability distribution and (in)efficiency was calculated according to [26] and [27] for each of these two models. Based on the correlation analysis, it can be stated that the choice of probability distribution had almost no effect on the resulting efficiency values, as the value of both the Spearman and Pearson correlation coefficients is 0.99. Therefore, a model with an exponential distribution was chosen to demonstrate the results. As

both correlation coefficients equal 1, it can be said that even the choice of the estimator has no effect on the efficiency values. Therefore, the [26] estimation was chosen to demonstrate the results.

After estimating the efficiency, other calculations were performed to obtain more detailed information. First, the Kruskal-Wallis test was used to determine the statistical significance of the factors "country" and "company size" on the efficiency of companies. Considering that in all periods both factors were statistically significant (p-value of the Kruskal-Wallis test <0.05), in view of the large scale of the analysis, only averaged values for individual companies for the entire monitored period are presented in Figure 1. The Kruskal-Wallis test for the average dataset also showed a p-value below 0.05 for both factors.

In the next step, the Wilcoxon test was performed to determine significant differences between a pair of groups. As for the results for the "country" factor, a statistically significant difference (p-value <0.01) was identified only in the case of the Czech Republic and Hungary, with Czech companies achieving better results in terms of the median efficiency values compared to Hungarian ones. Overall, Slovak companies show a significantly lower median efficiency compared to the Czech Republic (p-value 0.026). Hungarian companies in general achieve significantly lower values than Polish companies (p-value <0.01) and Slovak companies (p-value 0.013). For other pairs of countries, no statistically significant differences were identified in the median values.

Regarding only the factor "company size", statistically significant differences were found in all pairs except when comparing large and very large companies. According to the results, efficiency increases with the size of a company. A detailed view of the comparison of the median efficiency values for both company size and country is shown using boxplots in Figure 1. In Figure 1, the names of countries are represented only by abbreviations and are marked with different colors. Company size is then differentiated by the shade of the given color of the country where small companies are the lightest color and very large companies are the darkest.

Based on the combination of both factors, it can be concluded that small businesses achieve the lowest efficiency in all V4 countries. In contrast, very large companies achieve the highest efficiency. An interesting finding is the fact that the Czech Republic achieves the lowest median efficiency in the category of small businesses of all four countries, but in the other categories of medium, large, and very large companies, it achieves the highest median efficiency. The results indicate that the main factor for efficiency is the size of the company rather than the country in which the company operates.

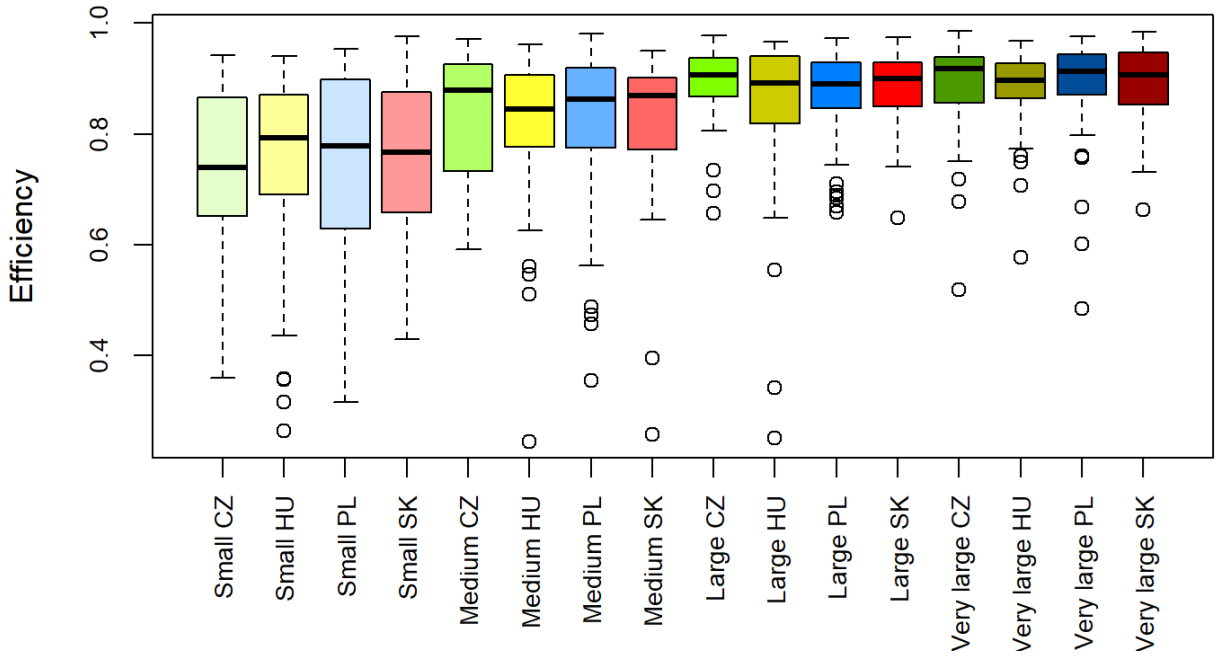


Fig. 1 Boxplots showing the efficiency of businesses considering size and country. Source: authors

Additional information on the development of efficiency is provided by the development of efficiency medians over time for the observed period as seen in Figure 2. Due to the higher significance of the factor of company size, medians over time are plotted primarily based on company size.

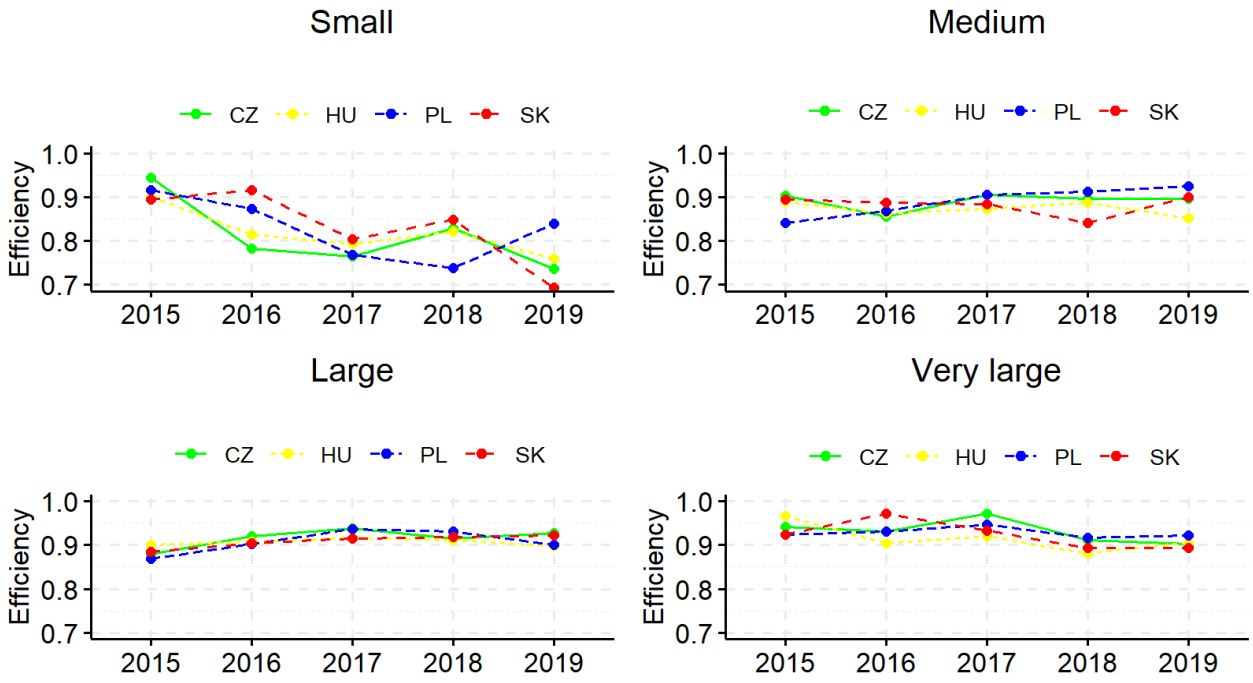


Fig. 2 Development of efficiency medians for the monitored period. Source: authors

Based on the median efficiency trend, it can be stated that the most interesting results are obtained by small companies. As can be seen, while the other categories achieve approximately constant median efficiency values, small companies not only achieve the lowest median efficiency

during the observed period, but also a relatively significant decrease. Within the category of small companies, there are also the highest differences between individual countries. On the contrary, other categories of companies show a similar trend in median efficiency for all countries.

4. Discussion

The analyzes carried out show that there are statistically significant differences in the level of efficiency achieved in the automotive industry in the V4 countries. However, these differences are not so much caused by the location of the companies, but rather by their size. As described above, the lowest efficiency is achieved by small companies regardless of the country in which they operate. On the contrary, the highest efficiency is achieved by large and very large companies. The finding of a positive relationship between company size and efficiency is consistent with the findings by Çalmaşur [10] conducted for Turkish companies. The significance of the effect of company size was also proven for other countries such as China, India, Indonesia, Italy, Japan, Malaysia, South Korea, Taiwan, and the USA (Stefanoni and Voltes-Dorta [3] and Fei and Li [2]).

The question remains of what causes small companies to achieve dramatically different levels of efficiency all over the world. Stefanoni and Voltes-Dorta [3] explained the differences by the possibility of using exclusive license agreements and thus using the know-how of foreign manufacturers. Fei and Li [2] point to the scale of production.

The very relationship between the size of a manufacturing company and efficiency is addressed in Halkos et al. [32]. The authors describe the level of liquidity, tangible assets, and sales as one of the main reasons for the higher efficiency of large companies. These factors can be identified as the main cause of productivity growth in the automotive industry. Large automotive companies with more capital can use better and newer technologies and know-how. They have more bargaining power and are generally checked by the company at all levels of the production process. The size of the company is also related to the number of employees, and smaller companies organize the production process in a different way than large companies. The higher efficiency of large companies is thus to some extent due to economies of scale.

A significant event that has affected the efficiency of the automotive sector is the coronavirus crisis of 2020. The impact of this crisis on the automotive industry was significant. There was a disruption of supplier-customer chains and, in some cases, the suspension of production. To quantify these impacts, companies operating in automotive industry in this period should be analyzed and then compared with the preceding period. However, the limitation is the low availability of the necessary data for the last two years. Therefore, this research remains open for further investigation.

5. Conclusion

The presented article deals with estimating the efficiency of companies in the automotive sector in the V4 countries based on the financial data obtained from individual enterprises. The empirical results show that in addition to the geographical area (countries), analyses of efficiency should consider not focus exclusively on the geographical area (countries) but also the size of companies. However, this can only be done based on micro data rather than aggregated macro data. According to the results, small companies show the worst performance in this sector. From the point of view of median efficiency, mainly small Czech companies are unable to keep up with the competition. Conversely, the best results (based on median efficiency values) are achieved by very large Czech companies. Differences in efficiency caused by the size of enterprises can be mainly related to returns to scale.

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