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EFFICIENCY ASSESSMENT OF HIGH-TECHNOLOGY EXPORTS USING THE DATA ENVELOPMENT ANALYSIS

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ABSTRACT

The purpose of this study is to assess the efficiency performance of high-technology exports. The empirical analysis uses the sample of selected South East Europe (SEE) and European Union (EU) countries in the year 2017. To provide the empirical evidence, we have used the data envelopment analysis (DEA). Our study does not only evaluate the performance of the countries of interest, but also aims to explain the differences in the efficiency scores. For this purpose, it uses Tobit regression. The findings of DEA analysis suggest the relatively small countries to be efficient. With regards to Tobit regression, exports share is found to have a direct positive link with the efficiency scores obtained from DMUs whereas the coefficient with The Global Innovation Index (GII) is not found to be significant.

KEYWORDS

ASSESSMENT, EFFICIENCY, DEA, HIGH-TECHNOLOGY

JEL CLASSIFICATION CODES

C01, G14, C55

1. INTRODUCTION

Technology tends to play very important role nowadays. Thereby, the role of technology and science in production has received much attention among research community. Taking into account the fact that technology can play a significant role in the cost reduction; entrepreneurs as well as the governments have both recognized its significant role in business. As a result, the investment in technology and science has become a very important objective for policy makers worldwide leading to the great increase in the sources directed to the science and technology (Zhou, 1999).

Although there is a significant development of technology in South East and European Union countries, there is still much room for the progress compared with Japan or United States. This is especially true for South East countries in the fields of high-tech industry. Apart from the fact that governments play a great role in the development of science and technology, business sector should also make a great effort for improvements in this light. Thereby, to have the improvements it is of crucial importance to have the input-output analysis of the efficiency of high-technology exports what was the motivation to conduct this study.

Lu et al. (2017) display the importance of the enterprises to introduce the new technology especially in developed economies. Bearing in mind that technology is in general connected to the macro level, there are many studies to date conducting the input-output analysis of the efficiency of exports. However, the efficiency of high-tech exporters has not been explored quite often. The necessity to conduct this research lies in the fact that these enterprises engaged in high-tech and tending to provide the new technological solution presented by their research team can significantly contribute to the economic growth as well as the development of technology.

Thereby, this research aims to examine the completion of high-tech export in South East and European Union countries. The motivation behind lies in the fact that the *Strategic Framework EU 2020* requires a balance in the level of development among EU countries. This analysis should result in a benchmark EU country that will be a role model for South East European countries seeking to become a full EU member state. High-tech products are related to IT industry, pharmacy, air transport etc. The most important characteristic of these products is high intensity in terms of research and development (Satrovic and Muslija, 2018). There are huge differences among EU member states in terms of the exports of high-tech products. Differences are substantial among OECD countries as well. High-tech and medium high-tech industries are the most intensive in Japan. In addition to research and development expenditure, special attention should be also given to knowhow as a positive externality.

This paper aimed to conduct the empirical research while including the most recent data. The last available are the data from 2017. Hence, the database in this paper includes input and output variables for the year 2017. The data sources are The World Bank, Eurostat and Global Innovation Index Report for 2017. The empirical analysis is conducted in two steps. In the first step, we have applied Data Envelopment Analysis (DEA) to estimate the efficiency scores for every single country in our sample. Furthermore, we have applied Tobit regression to give a possible explanation of the differences between inefficient regions. The Tobit regression differs from DEA since it prefers indirect inputs as well as externalities to direct inputs. From the best of our knowledge this is the first attempt to analyze the efficiency of high-tech export using the selected countries of interest what represents the first contribution to the literature. The second contribution is connected to the fact that we have employed the latest available data, while the third contribution arises from the fact that this research tends to provide the possible explanation of the differences between inefficient regions.

It turns out that economies of smaller countries (i.e., those of Luxembourg, Ireland and Malta) are more efficient than economies of Germany, France, and United Kingdom. Similar results are obtained by (Cullmann et al., 2009), applying different outputs and inputs. In order to explain these differences, Tobit model is employed. After the introductory remarks we have given a brief overview of the literature in Section 2. Section 3 presents the sources of the data as well as brief introduction to methodology. Empirical results concerning efficiency differences across South East Europe and European Union countries are represented in Section 4. This section also introduces Tobit model that is used to explain efficiency differences. Paper ends with concluding remarks and references.

2. LITERATURE REVIEW

Data envelopment analysis has been used for decades to evaluate the efficiency of high-tech export (knowledge-based export). For instance, Staníčková and Skokan (2012) have collected data for 27 European Union countries. They have employed DEA. Data of four input and two output indicators are collected. The results of this paper suggest there are only three countries that are efficient in the time span of interest. There are also five countries in the group "highly efficient" with the index close to one. Apart from these, all other countries are considered inefficient.

Saljoughian et al. (2013) attempted to measure the efficiency of the selected countries in the year 2009. The data were extracted from the World Bank database, which is a reliable source of information. The countries were ranked using the Andersen-Petersen model. This analysis has distinguished the efficient countries from the inefficient ones based on the six factors of science and technology. Based on the calculations, 19 countries were identified as efficient, and the remaining nine were classified as inefficient. Moreover, the roadmap to efficiency was suggested for some of the inefficient countries.

Main objective of Afzal and Lawrey (2012) study is to explore the efficiency of some of the Asian countries in terms of the knowledge-based economy. The empirical results suggest that the most efficient countries are Indonesia and Philippines (CRS assumption). Apart from these findings, the most efficient countries are Singapore, Thailand, Indonesia and the Philippines. The authors indicate that the benchmark country should be Philippines.

Importance and determinants of high-tech export were exploring by the different researchers (Todo, 2011; Ming, 2016; Sandu and Ciocanel, 2014, Movahedi, 2013; Yüksel, 2017; Harris and Moffat, 2011; Aw et al.2011) in large number of studies as well in different sample of countries (developing, more and less developed). The most important findings of these papers suggest the correlation between the exports of high-tech and R&D expenditure to be positive.

Lu et al. (2017) explore 10 high-technology enterprises and their efficiency for the sample of 29 provinces while Kabaklarli et al. (2018) conduct the similar research in the case of OECD countries in the time span between 1989 and 2015. The findings of this paper also advocate the positive impact of high-technology exports on economic growth in the long-term. The technology efficiency was the matter of interest in Xu and Liu (2017).

Manufacturing sector has recorded a decline over the last few decades in the many industrialized countries (Coad and Vezzani, 2017). In terms of the productivity of manufacturing sector it is important to emphasize the findings of Pradeep et al. (2017) in the case of Indian companies. Findings from this research indicate that foreign presence has a significant positive spillover effect on the productivity of Indian manufacturing firms when compared to alternative spillovers from R&D and export initiatives.

With regards to the high-tech exports, many researchers to date have treated the determinants of this macroeconomic variable. To mention a few, Śledziewska and Akhvlediani (2017) have conducted this analysis in the case of Visegrad countries. In addition, it is also of key importance to emphasize the fact that the link between high-tech exports and economic growth has been a popular research question in the last decades. For instance, Mehrara et al. (2017) suggest the positive link in the case of developing countries. These results are confirmed in the case of China by Wang et al. (2011).

Usai et al. (2013) analyzed both input (R&D expenditure) and output indicators (patent applications) for the 27 European countries and the 16 European Neighboring Countries. Applying data envelopment analysis, they have analyzed the main factors influencing the innovation process. Main idea was to adopt both parametric and non-parametric methods to investigate about the knowledge production function at the country level. The analysis is mainly speculative due to the absence of information about some potentially important phenomena, such as human capital. Nevertheless, main results are robust and confirm previous analysis at the country and regional level. Moreover, they add some original findings about the potential for catching up of European Neighboring Countries.

3. METHODOLOGY AND VARIABLES

Mathematical programming, which applies nonparametric DEA technique, provides the possibility to determine the efficiency of observed units in comparison to other units included in analysis, based on output and input variables. Thus, the efficiency curves create units that are relatively efficient in comparison to the other observed units, by maximizing their output variables with specified inputs. In subsequent economic and mathematical analysis two modified models: Charnes-Cooper-Rhodesov (CCR) model and

Banker-Charnes-Cooperov (BCC) model were derived from the model which was established by Charnes, Cooper and Rhodes in 1978. BCC model is used for the purpose of analysis conducted in this paper.

This model has been established in 1984 by Banker, Charnes and Cooper (BCC). It assumes that inputs are increased by *m*, and output increases by more than *m*. The model is specified in the following way:

$$\max h_k = \sum_{r=1}^{s} u_r y_{rk} + u_* \tag{1}$$

subject to:

$$\sum_{i=1}^{m} v_i x_{ik} = 1. \tag{2}$$

The most important step in the formulation of a DEA model is input and output variables selection since it can significantly improve the quality of results in further steps. The most important precondition in choosing BCC model input and output variables in this paper is to cover the high-tech export performance.

The first step in developing a model that is used to evaluate the high-tech export efficiency in the sample of interest is to identify the outputs which represent desired goals as well as its main inputs. Outputs that give the best description of the observed process, as well as of the overall business should be selected. The largest restriction of this model is subjectivity in the selection of type of the model and outputs. Analysts, researchers and decision makers should be aware of this restriction. In terms of DEA, authors face the most issues while selecting input and output variables. Even though it is a very difficult step, it requires great effort from authors since the quality of analysis highly relies on the selection of input and output variables. Special attention should be also given to the ratio between these variables in order to provide results as realistic as possible. There is no strict rule, but according to the practice the total number of outputs and inputs should be at least 3 to 5 times lower than the number of observed units (Jacobs, 2001).

In order to test the main idea of this research we propose four input variables (X): higher educational labor force, R&D expenditure as a percentage of GDP, number of researchers, university-business research collaboration. Output variables (Y) are high-tech export and GDP. The brief explanation of these variables is given below.

X_1: Employment rate of higher educational labor force is used as an indicator of the growth of intangible capital. In the last 30 years, European economies have given monetary effort to promote the production and dissemination of knowledge by investing in education, R&D activities and training.

X_2: The share of research and development expenditure in GDP (GERD) indicates the incentives of a given country in terms of research and innovation. Europe 2020 (EU development strategy) highly relies on the research, development as well as the innovation.

X_3 (number of researchers per mil people): This variable includes researchers and professionals engaged directly in the field of research and development), including persons providing direct services, such as managers, administrators, and clerical staff.

X_4: University-Business research collaboration. The focus of this measure is on the quality of the collaboration between universities and firms.

Y_1: Output variable (high–tech export): Commercialization and creating new technologies is one of the main objectives of the strategic framework of the EU strategy 2020. Eurostat and the European Commission have prepared many studies that analyze innovation both in the EU countries, and in the candidate countries. The share of high-tech exports in total exports is used as an output variable in this research. By the experts of the European Commission, this high-tech sector represents an essential driver of economic growth, labor productivity and generates value added.

Y_2: Output variable - gross domestic product (GDP) is used as a proxy of economic growth (Satrovic, 2018; Ahmad et al., 2019; Ullah et al., 2020).

Second phase of this research uses Tobit regression models to explain differences in the efficiency scores. The Tobit model can be estimated by the maximum likelihood method under the assumption of normally distributed errors. First Tobit regression was established for testing how related are the household expenditures on durable goods and the income. Today this is a tool for modeling variables in a wide range of fields such as econometrics, biometrics, agriculture and engineering. There is a large number of researchers that have used this tool to conduct empirical research: Amemiya, (1973), McConnel and Zetzman (1993), Anastasopoulos et al. (2008). The Tobit model can be formalized as (Eq. 3):

$$y^* = m(X) + \mathcal{E}$$

$$Y = \begin{cases} y^*, & y^* < 0 \\ 0, & otherwise \end{cases} \quad (3)$$

where:

Y* (dependent variable) - efficiency score retrieved from the DEA (Table 1);

X_1- exports share (Export Share By Country; Total Products as the percentage of the World total) X_2 - The Global Innovation Index.

4. RESULTS OF THE RESEARCH

Initially, we have analyzed the data by calculating the descriptive statistics (Table 1). The table displays an average value of X_1 to be 82.33%. The minimum value of 70.8% is reported in the case of Greece, while the maximum-recorded value of 90.2% is reported in the case of Malta. With regard to the GERD, it reaches the value of 1.38% on average. The maximum value is reported in the case of Sweden while the lowest value is displayed in the case of Bosnia and Herzegovina. Moreover, the table outlines the average value of X_3 to be 1.54. The maximum value is reported in the case of Austria while the lowest data can be again found in the case of Bosnia and Herzegovina. With regard to the X_4, the maximum university-business research collaboration is found in the case of Finland while the lowest value belongs to Greece. At last, the mean descriptive statistics is presented in the case of output variables.

Table 1. Summary statistics

Variable	Obs. numb	Mean	Std. Dev.	Min	Max
Employment rate- higher educational labor force	33	82.33	5.74	70.80	90.20
GERD	33	1.38	0.88	0.22	3.25
Researchers	33	1.54	0.79	0.22	2.92
University-Business research collaboration	33	3.98	0.91	2.55	5.64
High–tech export	33	10.73	7.20	1.20	34.30
GDP	33	23.15	17.20	4.58	80.30

The results of this research advocate the significant differences in efficiency in the case of countries of interest. It turned out that the Luxembourg, Ireland and Malta are only efficient countries considering high-tech export performance (Table 2). Staníčková and Skokan (2012) display the similar results in the last year of their research (2010). According to their research Malta and Luxemburg were efficient. In addition, Ireland is recognized as highly efficient country in the year 2010 by Staníčková and Skokan (2012).

France is positioned first in terms of inefficient countries followed by: Finland, Sweden, Cyprus, Netherlands and Hungary. An appealing result is the fact that Serbia is the best positioned out of the selected SEE countries. Portugal takes lowest level of efficiency. The fact that some countries as Bosnia and Herzegovina employ a high percentage of highly educated labor force, and take very low position in individual efficiency in high-tech exports is especially considering. These findings suggest that the most efficient countries in terms of high-tech exports are those with the highest level of university-business research collaboration and high-tech export. Taking into account these statistics in the countries of interest, the results in the Table 2 are in accordance with the expectations.

The Tobit regression analysis uses the efficiency scores as the dependent variables. Several different techniques can be used to determine the link between the technical efficiency score and the other factors. One of the most important methods is Tobit regression. This is why it has been employed in the present research. Table 3 provides brief summary statistics on the variables used in Tobit model.

Table 2. Efficiency/inefficiency rank

	Efficient DMUs	Frequency of reference
1	Luxembourg	1
1	Ireland	2
1	Malta	3
Inefficiency	Inefficient DMU	Rank
0.865453	France	4
0.852284	Finland	5
0.804298	Sweden	6
0.774278	Cyprus	7
0.720027	Netherlands	8
0.697375	Hungary	9
0.660447	Denmark	10
0.659454	Greece	11
0.648833	Latvia	12
0.634477	Germany	13
0.602912	Slovakia	14
0.599574	Austria	15
0.58895	Slovenia	16
0.586767	United Kingdom	17
0.582426	Czech Republic	18
0.570082	Belgium	19
0.565609	Croatia	20
0.563859	Italy	21
0.549021	Poland	22
0.536994	Spain	23
0.516911	Montenegro	24
0.493147	Serbia	25
0.478655	Romania	26
0.464706	Estonia	27
0.444255	FYR Macedonia	28
0.405233	Turkey	29
0.366795	B&H	30
0.337534	Lithuania	31
0.330096	Bulgaria	32
0.290719	Portugal	33

The brief explanation of the variables is given as following: Y (dependent variable) - efficiency score retrieved from the DEA (Table 2); X1- exports share (Export Share by Country; Total Products as the percentage of the World total) and X2 - The Global Innovation Index (GII) is used to describe the performance of 126 economies globally in terms of the innovation.

Table 3. Descriptive statistics of variables in Tobit model

Variable	Obs	Mean	Std. Dev.	Min	Max
Efficiency	33	0.29	0.20	0.29	1.00
Exports share	33	1.08	1.58	0.01	7.67
GII	33	47.12	9.08	29.8	63.3

Out of the 33 observed SEE and EU countries, the maximum value of export share of 7.67% is reported for Germany. The lowest level of exports shares (0.01) has been recorded in the case of Montenegro. On average, exports share is showed to be 1.08. According to results in Table 4, highest level of Global Innovation Index is 63.3 for Netherlands and the lowest level is for FYR Macedonia. On average, GII is displayed to be 47.12.

Table 4. Tobit regression

					Number of obs =	33
					LR chi2(2) =	19.50
Log likelihood = 12.690744					Prob > chi2 =	0.0001
					Pseudo R2 =	-3.3169
Efficiency	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
Exports share	0.015	0.003	4.36	0.000	0.008	0.022
GII	0.001	0.020	0.06	0.956	-0.039	0.042
Cons	0.072	0.155	0.47	0.644	-0.244	0.388
/sigma	0.151	0.019			0.111	0.190
Obs. summary:		0 left-censored observations 31 uncensored observations 2 right-censored observations at efficiency>=1				

As indicated in methodology, this research proceeds to the estimation of Tobit regression. Table 4 summarizes the obtained results. We employ Tobit regression to test the comparative advantage principle in Ricardo and Heckscher-Ohlin model of international trade. Both of these models may be used as a conceptual basis for the arrangement of trade relations. First of this two models, Ricardo's comparative advantage model is based on relation between trade and labor productivity with different levels of technology.

Exporting countries that dispose with the high amount of the factor labor will in general produce and export labor-intensive products. However, those that pay much attention to the knowledge as a factor of production, will produce the goods with the higher value added. Thus, our results are in line to this theory since exports share has a significant positive impact on the efficiency level. This research can be of great importance for policy makers since it suggests that countries need to improve the exports share in order to catch up the efficient high-tech exporters. Moreover, the Table 4 suggests that GII has no significant impact and cannot help to decrease the gap between efficient and inefficient high-tech exporters. Thus, the particular attention should be paid to the structure of the exported products. There is a necessity for countries to conduct a serious research to find and specialize in a certain high-tech product and to be more competitive compared to the other high-tech exporters. These results suggest the great importance of the specialization.

5. CONCLUSION

Main subject of this paper was the investigation of efficiency differences of the high-tech export performance for selected SEE and EU countries in the year 2017. To evaluate country's high-tech export, Data Envelopment Analysis (DEA) has been applied in first stage of analysis. For the second stage of this research, Tobit regression models have been used. This paper uses four input variables and two output variables.

According to the DEA estimates in efficiency, it turned out that the Luxembourg, Ireland and Malta are only efficient countries, considering high-tech export performance. Inefficiency results indicate that almost all of the SEE's countries have lower efficiency level comparing to EU countries. For inefficient countries, the highest rank has been reported in France followed by: Finland, Sweden, Cyprus, Netherlands and Hungary. Serbia is the best positioned out of selected SEE countries. Portugal is the least efficient country. The fact that some countries as Bosnia and Herzegovina employ a high percentage of highly educated labor force, and report low level of high-tech exports efficiency is especially considering. These results are clear indicator for policy makers in Bosnia and Herzegovina that there is a necessity to improve the efficiency of high-tech exports since there is a huge potential in terms of human capital. This is even more important since high-technology exports tend to be an important determinant of economic growth especially in developing countries.

Second part of the study employs Tobit regression model. Explanatory variables include GII and exports share while efficiency scores are used as the dependent variable. The results of this paper suggest a positive impact of exports share, while the impact of GII is not found to be significant for a 5% level of significance. Luxembourg, Ireland and Malta are found to be the benchmark countries. Thus, in order to improve the high-tech exports efficiency, there is a necessity for both, SEE and EU member states to learn a positive praxis from these three countries and to try to use these examples in order to improve the statistics in terms of high-tech exports efficiency. Thus, policy makers need to bear in mind the positive praxis of these three countries while creating strategies on the high-tech exports. The recommendation for future research is to take into account more periods of time in order to make a comparison. Besides that, the sample of the countries can be enlarged. As the last recommendation, it would be interesting to employ time-series methodology to check the link between the variables of interest for the best and least ranked countries.

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