KEY PERFORMANCE
DRIVERS OF THE SEAPORTS
IN UKRAINE

by

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Kyiv School of Economics

Abstract

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Ukraine is heavily integrated into international trade with significant export capacities (41% of GDP), out of which 57% of the volume is shipped by the sea. This importance contrasts with ports' poor infrastructure quality and high port tariffs. This study decomposes the efficiency of ports, eventually aiming to curtail losses and improve cargo volumes. With SFA and order-α methodology, we estimated efficiency scores for Ukrainian ports for 2006-2020 and defined Yuzhnyi, Mykolaiv, Odesa, and Chornomorsk as the best performing ports. The most important performance driver for ports is the infrastructure index. Similarly, tariff reduction by 10% promises efficiency score improvements by 0.01. Ports with higher port capacity also exhibit higher efficiency scores, while specialization does not affect their performance.

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LIST OF ABBREVIATIONS

DEA. Data Envelopment Analysis.

FDH. Free Disposable Hull.

SFA. Stochastic Frontier Analysis.

USPA. Ukrainian Sea Port Administration.

WEF. World Economic Forum.

Chapter 1

INTRODUCTION

As a country heavily integrated into international trade with 90.17% of the volume of trade to GDP ratio in 2019, Ukraine heavily relies on the quality and efficiency of its infrastructure network. According to the State Statistics Service, Ukrainian maritime transport is responsible for exporting more than 57% of the country's total export volumes. Moreover, we observe a sound upward trend in the total amount of exports passing through Ukrainian seaports, which increased by 85% since 2013, reaching 121m tons in 2019. Such statistics highlight the vital importance of the port industry for the Ukrainian economy. International outlook also confirms that maritime transport is a backbone of the world economy since 80% of global trade volumes pass through seaports' gates (United Nations Conference on Trade and Development 2019).

The port efficiency, meaning the ability to maximize the output with given inputs, is considered an important global benchmark in the industry. Figure 1 represents the cross-country ranking on the scale from zero to seven of seaport efficiency reported by The Global Competitiveness Report by World Economic Forum (WEF). Ukrainian seaports scored low below its European neighbors and trade partners compared to other transportation modes in the country. Ukrainian ports' performance takes 78th place in global rating in 2019, leaving behind only countries as Armenia, Georgia, and Moldova with much lower dependence on export and importance of sea-borne trade; while Germany, Poland, and other European countries, including Estonia, Latvia, and Lithuania from the post-soviet bloc, demonstrate notably higher efficiency scores. Nonetheless, Ukraine displays positive dynamics in terms of the efficiency of domestic seaports. In 2017, its rank was 92nd out of 137 countries, and in 2018 it was already 77th, 15 positions higher than a year before. However, this improvement is considered insubstantial compared to the positioning of Ukrainian railways, the dominant transportation mode in the country, ranked 34th globally with a score of 4.2 out of 7 points.

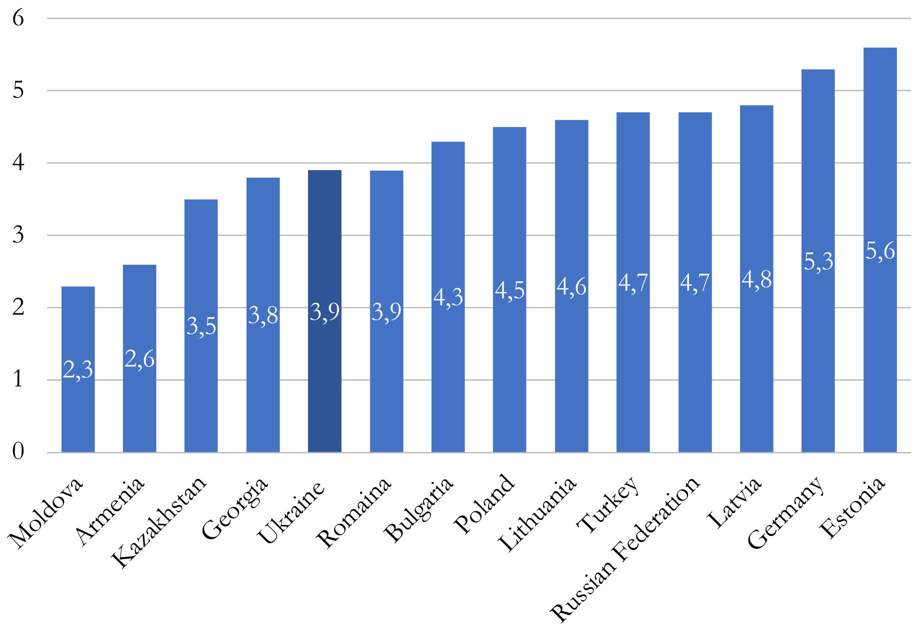

Figure 1. Cross-country ranking of seaport efficiency, WEF 2019

The great importance of the port industry in Ukraine goes in stark contrast with the country's poor quality of existing port infrastructure, which scored 3.9 out of 7 in 2019 according to the WEF measurement. On top of it, the domestic port charges exceed the port charges across the world almost in 2.5 times, according to the Ministry of Infrastructure in 2016 (Pop et al., 2019). Thus, obsolete infrastructure combined with high port tariffs makes Ukrainian ports unattractive transportation options for international trade, thus hindering their competitiveness with other transportation modes and other countries. Empirical evidence suggests that efficiency improvement might substantially curtail losses from shipping costs and result in higher cargo throughputs (Dollar, Clark and Micco, 2002). Thus, it suggests the high practical value of understanding and studying the efficiency of seaports in Ukraine.

In the first place, this study aims at contributing to the industry's policy-making environment by creating a foundation for an efficiency-based scoring system for seaports in Ukraine. All current ports' ranking, such as the annual National Maritime Rating of Ukraine by "Ports of Ukraine" publisher, use only cargo volumes to compare ports performance, and they completely overlook the efficiency criteria. Such ignorance might be even distortive for a business environment, as ports with extensive capacities might simply mismanage their resources but still enjoy top positions on the list. Thus, having a comprehensive efficiency ranking across the Ukrainian ports will enhance the infrastructure's competitiveness, serving as a reference point for domestic exporters, businesses, national authorities, and international bodies.

Secondly, this study aims at contributing to monitoring efforts in the port industry, leading to its better understanding and, consequently, to more prudent decision-making, for example considering new investment projects. Arising opportunities for the port industry attract investments in port infrastructure, the amount of which has more than tripled since 2015. Large holdings and exporters of agricultural commodities, as "Kernel" and "Nibulon," are highly interested in developing port infrastructure, allowing them to supply greater volumes of export products. Such investment projects predominately focus on the construction of new terminals, targeting primarily the top 5 biggest ports. However, before extending the port capacity, it is crucial to understand whether existing facilities are fully exploited and whether the output is maximized. Thus, operational efficiency measurements can become a valuable management tool for investment decisions as efficiency determinants will help interpret the port's weakness and identify improvement points. The port performance measurement can also become a meaningful input for port administration, given the ongoing discussion on tariff reduction for Ukrainian ports.

Overall, this study aims at evaluating the efficiency of the Ukrainian seaports with a particular focus on the determinants of their efficiency. Three hypotheses are suggested for testing. Firstly, we question whether large ports are more efficient than small ones, meaning that port size has a positive effect on the efficiency score. Although large ports enjoy greater cargo flows, they do not always exhibit greater efficiency compared to the small ones – the evidence to which we will return in the following chapter. The second hypothesis tests whether expensive port tariffs are associated with higher port inefficiencies. And lastly, we will test whether port specialization contributes positively to efficiency. There are several ports in Ukraine, which are specialized in grain cargo, while other ports process different cargo types, so one has to check whether specialization on specific cargo type is one of the determinants of port efficiency. These hypotheses stipulate the novelty of the study, along with unique methodology and variables choice for the modeling. Apart from its practical implications, this study would also contribute to scarce research studies on the Ukrainian port industry.

This study has the following structure: the next section of the thesis provides an overview of empirical studies related to port efficiency, which are considered most relevant for this research. This is followed by Chapter 3, which discusses the two proposed methodologies. The outlook of the Ukrainian port industry, along with the description of the dataset and model variables, is presented in Chapter 4. Chapter 5 reports the results of modeling and explains key findings. The last section of the study summarizes and concludes the paper. It also presents the implication of conducted analysis to the port industry and ideas for further research.

C h a p t e r   2

LITERATURE REVIEW

The first studies on port efficiencies dated to 1990. However, since then, seaport efficiency has been under the scope of research for numerous coastal countries and regions that rely on maritime transport (Cullinane and Wang, 2006; Niavis and Tsekeris, 2012). Such increasing attention for maritime transportation is attributed to globalization and escalating volumes of international trade. Moreover, the port industry becomes of increasing academic interest, which is reflected in abundant literature on the efficiency and competitiveness of seaports.

Productivity frontier analysis has been a widely accepted framework for efficiency estimations. The methodologies for productivity frontier analysis are distinguished between parametric and non-parametric methods. The SFA, stochastic frontier analysis, is widely used as a parametric method, while the Data Envelopment Analysis (DEA) and Free Disposable Hull (FDH) are the most prevalent non-parametric methodology.

Numerous papers incorporate SFA methods for efficiency estimates for the port industry (Ngangaji, 2019; Chen, Chou, and Hsieh, 2018; Konstantinidis, 2016). Researchers prefer SFA to other regression analysis methods like ordinary least squares because it allows calculating inefficiencies based on various distributional assumptions of the inefficiency term, meaning that different ports or production units have different inefficiencies (Liu, 2010). However, the estimations obtained from SFA are highly dependent on the choice of functional form (e.g., Cobb-Douglas or translog) and assumptions about the inefficiency term distribution (e.g., exponential, half-normal, or truncated). Nevertheless, Cullinane and Wang (2006) showed that SFA estimates under these three distributional assumptions are highly correlated, suggesting that port rank order made based on SFA is robust to the distributional specifications.

Despite an abundance of studies employing DEA in the context of port efficiency (Nikolina and Jian Hua, 2020; Quintano, Mazzocchi, and Rocca, 2020), the method is not suitable to apply for the study. With only 18 decision-making units (all the Ukrainian ports) and the substantially larger number of performance measures (inputs in our case), the problem of discrimination between efficient and inefficient ports, often referred to as "the curse of dimensionality," arises, preventing from getting valuable data insights (Charles, Aparicio and Zhu 2019). FDH methodology represents a better option, however, this method is heavily criticized in the literature due to its high sensitivity to outliers (Cazals, Florens and Simar 2002). Addressing these shortcomings, a partial frontier approach has been developed, namely a generalization of FDH the order-α methodology, but which eliminates certain DMU from the estimation of the frontier (Aragon, Daouia and Thomas-Agnan 2005). Surprisingly, comparatively few port studies employ order-α methodology, with Figueiredo De Oliveira and Cariou (2015) claimed to be the first ones to incorporate order-α as the first step in similar research. However, it is widely used for research on regional efficiency and in the agriculture field. Although order-α methodology, as well as other non-parametric methods, manages to estimate the efficiencies, it does not name the factors that cause such inefficiencies. Thus, many studies extend their analysis to the second stage of estimations, when a truncated regression is conducted (Niavis and Tsekeris 2012; Demchuk and Zelenyuk 2009; Figueiredo De Oliveira and Cariou 2015).

Despite parametric and non-parametric methodologies ground on different assumptions, Ngangaji (2019), Hlali (2018), and Kammoun (2018) use both approaches, which allows comparing results and ports ranking. Notable that those estimates tend to have a high correlation with each other, often giving similar rankings (Quintano, Mazzocchi, and Rocca, 2020). Taking into account that each methodology has its strengths and limitations, in this study, we will also proceed with both SFA and order-α methodologies.

Data selection is an integral part of the studies on port efficiency estimations. For these modeling exercises, it is recommended to use panel data instead of cross-sectional (Cullinane et al. 2004). Authors argue that panel data present more reliable evidence as it manages to capture efficiency trends, while the estimations with cross-sectional data can be biased if ignoring the efficiency fluctuations over time. Noteworthy, in reviewed studies on port efficiency, the sample size might vary from 6 to 108 ports or terminals (Konstantinidis, 2016; Ugboma and Oyesiku, 2020). However, one has to be cautious as the small sample size might result in unstable and inefficient estimates (Niavis and Tsekeris, 2012).

One of the distinguishing features of each analyzed study is the choice of contextual variables, which help explain the variability in efficiency scores; thus, define the drivers of inefficiencies. The geographical position is a fundamental characteristic of port performance, as usually, regions with intensive sea-borne trade flow process large amounts of cargo volumes, and ports in developed countries score higher at the efficiency scale. In the study of the ports in South-Eastern Europe, Niavis and Tsekeris (2012) use the distance of each port from Suez to control for the port's relative importance. They also add a GDP per capita and a population of the region as a control for the economic environment of the territory. The results showed the significance of the remoteness from Suez, implying that ports located closer to Suez benefited from the location near the international sea trade corridor. Alternatively, the geographical position is controlled through the factor variables for regions. In a study on 35 top international container ports, Chen, Chou, and Hsieh (2018), using the region variable found that Asia-Pacific ports appear to be more efficient in output than those in Europe and America.

Using panel data, it is possible to examine the efficiency fluctuations over time; thus, a time trend is often added to the model. It can capture the effect of structural changes in ports of the studied sample, as was illustrated in the work of Barros (2003). The author found a positive relation of efficiency of Portuguese ports and time trend for the period 1990-2000, which can be explained as a conducive effect of European integration of Portugal, which brought financial aid and investments to the port industry and increased competition with neighboring European ports.

Several studies on port efficiency suggest controlling for the size of the ports, which appear to be a statistically significant efficiency score determinant. In the study on 30 seaports in South-Eastern Europe, Niavis and Tsekeris (2012) add ports' total area to capture the size effect on efficiency and found a positive relationship, implying that larger ports operate more efficiently than the smaller ones. Controlling similarly for ports' area, Salem Al-Eraqi et al. (2010) made an opposite conclusion for 22 cargo ports in the Middle East and African countries. Additionally, addressing the peculiarities of the studied port industry authors control for the regulatory status of the port (private or public), terminal type (container terminal or not), the Liner shipping connectivity index, which proxied accessibility to global trade (Barros, 2003; Ding et al., 2015; Chen, Chou and Hsieh, 2018). Another suggestion for the contextual variable came from Zghidi (2017), who used the specialization index to address the degree of terminal diversification. The variable appeared to be significant and positively related to the efficiency score, indicating that efficient ports should be diversified and non-specialized.

Despite the abundance of international research on efficiency in the port industry, the study on the efficiency of Ukrainian seaports was not conducted on such a scale or represented a merely descriptive analysis. None of the existing papers name the causes of inefficiencies and the ways how those can be improved. The efficiency of Ukrainian seaports has been researched in the context of seaport tariffs. Bobylova (2019) found evidence of a negative effect of port tariffs on ports' efficiency and the positive effect of port efficiency on Ukrainian cargo handlings. This thesis work will extend the efficiency analysis of Ukrainian seaports further on. Apart from estimating efficiency scores, we aim to decompose the factors that explain port efficiency and build policy recommendations for efficiency improvements. Moreover, in addition to the previously employed SFA methodology, we will incorporate estimations with order-α methodology. And most importantly, this work will use a much richer dataset which accounts for several crucial components: variation in port characteristics in time, namely construction of new terminals and port deepening works; variation of port tariffs across the ports and in time; port tariffs discounts granted by the Ukrainian Sea Port Administration (USPA).

Chapter 3

METHODOLOGY

Economic efficiency refers to the comparison between the observed and optimal values of inputs and outputs (depending on model orientation, it is either a minimum of inputs or a maximum of outputs), which are part of the production process. Economic efficiency is decomposed into two components: technical and allocative efficiency. The former relates to producing as much output as inputs allow or to using as few inputs to produce a certain output, which corresponds to output-oriented and input-oriented technical efficiency, respectively. One of the components of technical efficiency is scale efficiency, which reflects whether the port operates at the optimal or suboptimal size. The allocative efficiency refers to the optimal combinations of inputs and outputs within prevailing prices (Fried, Lovell and Schmidt 1993).

The literature on operational efficiency measurements grounds on the theoretical concept of production frontier. The main idea is to estimate the "frontier" under which efficient units operate on this frontier, while inefficient ones operate below the defined production frontier (Cullinane and Song, 2006). Thus, the aim is to estimate the deviations from the idealized frontier. Following Lin and Tseng (2005), the output-oriented production frontier model will be used aiming to maximize the output with a given level of inputs; opposing the input orientation model that posits that the production goal is to minimize inputs to produce a given level of output. This choice is also supported by the fact that port authorities are mostly interested in output increase, and it is very costly and almost nonsensical to reduce ports' inputs, such as quay length and berth size.

Figure 2, adapted from Coelli et al. (2005), illustrates a production frontier for two outputs y_1 and y_2, and an input x. Port A, which lies below an isoquant ZZ' represents an inefficient firm. The segment AB is the technical inefficiency of port A, which is proportioned to output that could be achieved without increasing the amount of input. The measurement of technical inefficiency is defined as the ratio OA/OB.

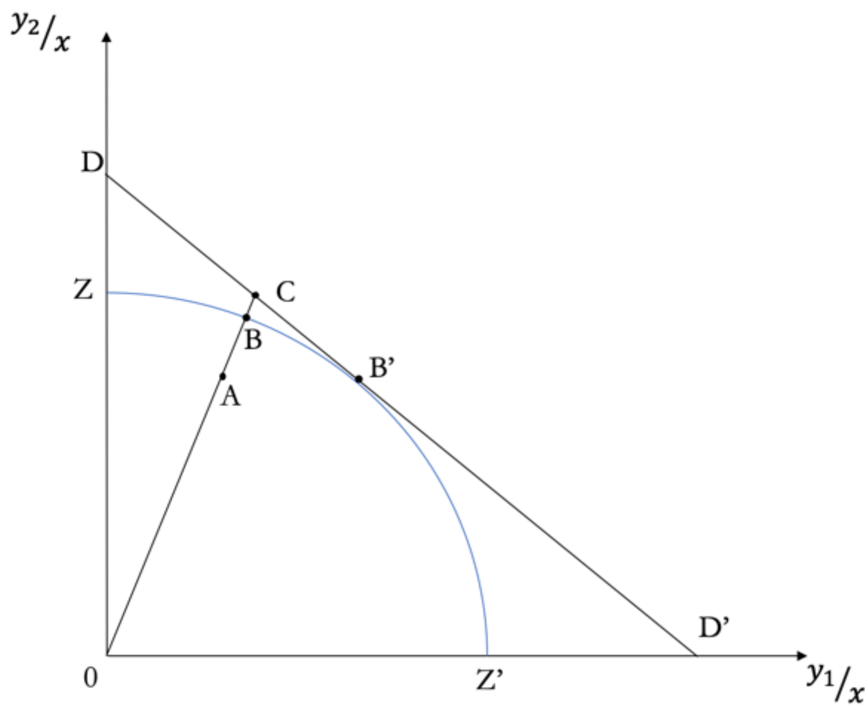

Figure 2. Output-oriented efficiency measurements

The parametric and non-parametric methods of frontier analysis, such as SFA and DEA, take inputs and outputs of the port production to yield the efficiency estimate. From the foundations of the production theory, the inputs for port production denote labor, land, and equipment. However, based on the difficulty of collecting and comparing data from non-homogeneous sources, an alternative approach was developed. Instead, the key physical characteristics are used as input variables in the model, such as length of quays, number of berths, port area, number of cranes used in the port (Cullinane and Song, 2006). The output is generally defined as the annual cargo turnover in tons or the container throughput measured in TEUs[1].

3.1 Stochastic Frontier Analysis (SFA)

In this study, SFA will be applied for panel data, following the specification of Greene (2005), who suggested the True Fixed effect stochastic frontier model address the problem of heterogeneity in the sample for efficiency estimations. The model modification can yield consistent estimates and appears to be a good predictor of technical efficiency even with small biases in parameters. SFA methodology imposes a specific functional form for the production frontier and employs econometrical methods to estimate its parameters. The model is defined as follows:

$$Y_{it} = f(X_{it}, Z_{it}, \beta, \tau) * e^{(v_{it} - u_{it})}, i = 1,2,..N, t = 1,2,.. \quad (1)$$

or in logarithmic form

$$y_{it} = \alpha_i + \beta' x_{it} + \tau' z_{it} + v_{it} - u_{it} \quad (2)$$

where Y_{it} denotes the output of each i-th port in t-th time period; α_i is a port-specific estimate, which captures unobserved time-invariant heterogeneity of all ports, enabling to define time-invariant inefficiency for each port separately. X_{it} stands for a vector of (1xm) dimension with production inputs for the i-th port in the t-th time period as values; Z_i defines a (1xk) vector of contextual variables; β and τ are (1xm) and (1xk) vectors of parameters that

[1] Twenty-foot Equivalent Unit

are to be estimated; v_{it}, u_{it} represent the random terms that denote statistical noise and inefficiency, respectively, which are mutually independent.

We also must posit assumption on the distribution of the random terms: we assume $v_i \sim N(0, \sigma^2)$, meaning i.i.d Normal distribution for its vector components, and $u_i \sim N^+(0, \sigma^2)$, meaning the vector has all positive values which have half-normal distribution.

3.2 Order-α frontier

The baseline of the order-α method is the FDH model (Tauchmann 2012). The idea is to compare each decision-making unit, port i in our case, with a set of all other ports in the sample j$= 1,2, .. M$ that produce at least the same output as port i. Out of all ports in consideration, the port which uses the minimum inputs is considered as a benchmark to i and is given the efficiency score equal 1. The efficiency score is estimated as

$$\theta_i = \min_j \max_{k=1,..K} \left(\frac{x_{kj}}{x_{ki}}\right) \tag{3}$$

However, in case the sample contains some outlying values, the estimates would be severely distorted. Thus, order-α approach is used to make the method more robust. Instead, of using for benchmarking all peers with at least the same output, order- α estimator uses $(100 - \alpha)$ percentile of the sample. Hence, α specifies what percentile of peers will be considered as superefficient and will not be enveloped by the estimated frontier. The efficiency score estimator has the following form:

$$\theta_i = \mathrm{P}_{\underset{j}{(100-\alpha)}} \max_{k=1,..K} \left(\frac{x_{kj}}{x_{ki}}\right) \tag{4}$$

In order to be able to interpret the order-α estimates and estimate the relationship of efficiency scores and explanatory variables, the second stage with truncated regression will be conducted. The equation for it is as follows:

$$\theta_i = \delta z_i + w_i, i = 1,2,..n \tag{5}$$

where θ_i is estimated in the first-stage efficiency score, z_i is a vector elements of explanatory variables for inefficiency, δ is the vector of parameters, and w_i denotes a statistical error. Following Demchuk and Zelenyuk (2009), we assume this error term to have a truncated normal distribution $N(0, \sigma_w^2)$ with the point of truncation being $1 - \delta' z_i$.

Chapter 4

DATA DESCRIPTION

This study will use the dataset constructed from the data available from the Ukrainian Sea Ports Administration (USPA) reports from 2006-2020. As unbalanced panel in total, it comprises 235 observations as several Crimean ports will be excluded from the sample since 2014. Physical characteristics of each ports are taken from the Hydraulic Structures Register, which is a database that includes information on the technical characteristics and technical conditions of all hydraulic structures in Ukraine. This register was formed after the reform of 2013, the results of which will be described later in this chapter, and contributed to monitoring and controlling mechanisms of USPA. Before proceeding with the description of the variables used for modelling, it is insightful to take a closer look at the Ukrainian port industry, its history and recent changes.

4.1 The overview of the Ukrainian port industry

Ukrainian port infrastructure consists of 18 ports located at the shores of the Black and Azov Sea presented in Figure 3. They can be divided into five geographic regions: the Odesa region includes ports of Bilhorod-Dnistrovskyi, Odessa, Chornomorsk and Yuzhnyi; the ports of Izmail, Reni, Ust-Dunaisk connecting the shores of Dunai river with the Black sea comprise the Dunai region; ports of Kherson, Skadovsk, Mykolaiv and Olvia form the region of Dnirpo mouth; Azov region unites ports which are located on the shores of the Azov sea and connects to the Black sea and further to the world trade flows via the Kerch Strait. The last 5 ports – Yevpatoriya, Sevastopol, Yalta, Feodosiya and Kerch ports are located in Crimean Peninsula bordering the Black sea, and together comprise the Crimea region. After the Crimea peninsula's annexation in 2014, all five Crimean ports were expropriated from the Ukrainian government. Despite these ports were not of high-priority in terms of annual cargo volumes (the share of each port in total cargo did not exceed 5% as of 2012), it was a significant upheaval to port industry and the domestic economy overall, resulting in the significant drop in total volumes processed in ports that year. Since then, the number of ports under Ukrainian control curtailed to 13.

Figure 3. The geographical location of Ukrainian seaports

All of the Ukrainian ports are the subjects of regulation by the state-owned enterprise Ukrainian Sea Port Administration, which was created in 2013 after a notable reform of the port industry. Since then, the USPA is in charge of efficient exploitation of its property along with reconstruction and maintenance of existing infrastructure, while governmental stevedore companies are to conduct commercial activities in the ports. In addition, the reform of 2013 redefined the definition of the port, and established it as a geographical concept determined by the water area boundaries. One of the most important contributions of the reform of 2013 is highlighting the importance of establishing port tariffs according to the methodology, which, however, so far, has not been agreed upon. The same reform also gave an opportunity to launch concession programs in the future, and in 2019 came a watershed moment, when the government signed a law "About concession,"[2] which opened doors for concession activity and attraction of private capital to state-owned assets. Shortly after that, in June 2020, the national authorities signed the first concession agreement for the commercial port of Kherson for 30 years to the concessionaire company Risoil-Kherson LLC. The Olvia port (before 2017 named Oktyabrsk) in the Mykolaiv oblast becomes the second port given to concession to Qatar-based port operator QTerminals in August 2020. According to international practice, concession agreements are a potent way to attract international investors and bring hefty investments in the sector and stimulate infrastructure development and job creation. Supporting this goal, the officials expect more concession projects to come in the future for ports Chornomorsk, Berdyansk, and Odesa, including its passenger terminals.

By the end of 2020, ports Yuzhniy, Mykolaiv, Chornomorsk, and Odesa become the largest ports, each shipping more than 15% of gross volume. Today these top four ports accounted for processing 88% of total annual cargo volumes. However, the shares of all the remaining other nine ports do not exceed 5% of the yearly gross volume. Figure 4 illustrates the spread of total cargo on the ten largest ports in 2020. Such a substantial difference can be easily explained by different ports' resource bases and physical capacities. It is no surprise that the four top-performing ports have the highest port capacities, the maximum depth of water, and can serve the widest vessels. Thus, small-scale cargo volumes in other ports do not directly imply bad

[2] Law of Ukraine "On Concession" dated 3.10.2019 № 155-IX

performance or imprudent management, but rather the limited port physical characteristics. The average annual cargo volume across the ports was 12.24 million tons of cargo in 2020.

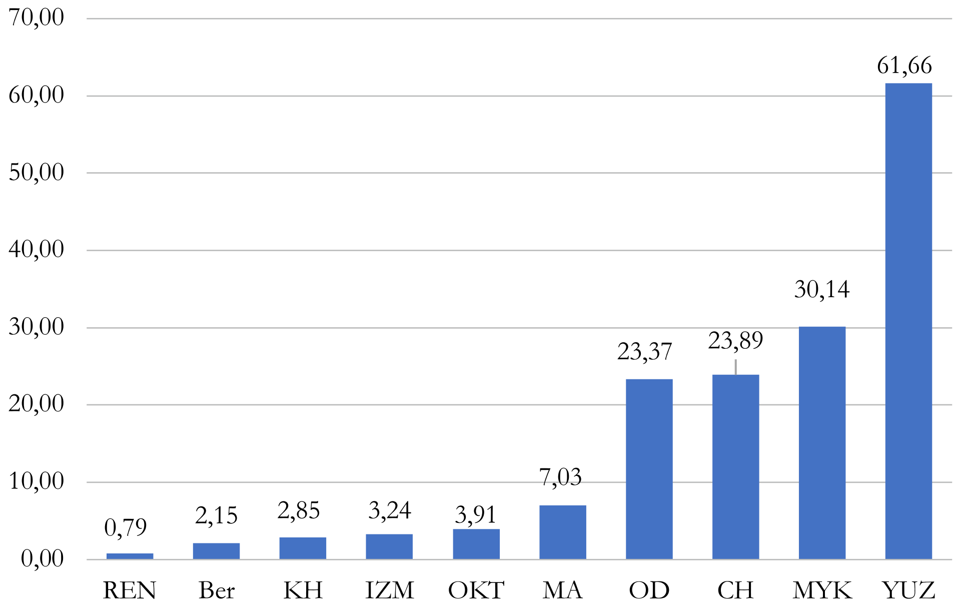

Figure 4. Average annual cargo volumes in millions of tons for largest ports 2006-2020

Domestic seaports are an indispensable part of the realization of Ukrainian export, as 77% of total cargo volumes passed through the gates of seaports in 2019 were dedicated to export, as data suggest. The evolution of the structure of the aggregate cargo traffic processing by ports is depicted in Figure 5. After a short period of growth in 2006-2006, starting from 2008 a steady decline started to deteriorate the total amount of cargo volumes processed in the ports. In 2016 after the reform of 2013 and adjustments after political instability of 2014, we notice increasing volumes of total cargo shipped though the ports up until recent 2020, when COVID pandemic hindered international trade. However, the decline was dismal, in total less than 1% or 1 million tons of cargo. As for distribution of commodity freights, the dominant freight types are the dry bulk commodities such as grains and metals, with its share in a total volume equal to 62% in 2019 and continuously increasing. Liquid and general bulk take 6% and 20%, respectively; however, both segments experience growth in cargo volumes. Moreover, the market reports a rise in container shipments, which might reallocate more weight for general cargo in the future. Terminals in Odesa, Yuzhniy, and Chornomorsk serve the container lines with a throughput of more than one million tons in 2019, exceeding a previous year's volume by 18%.

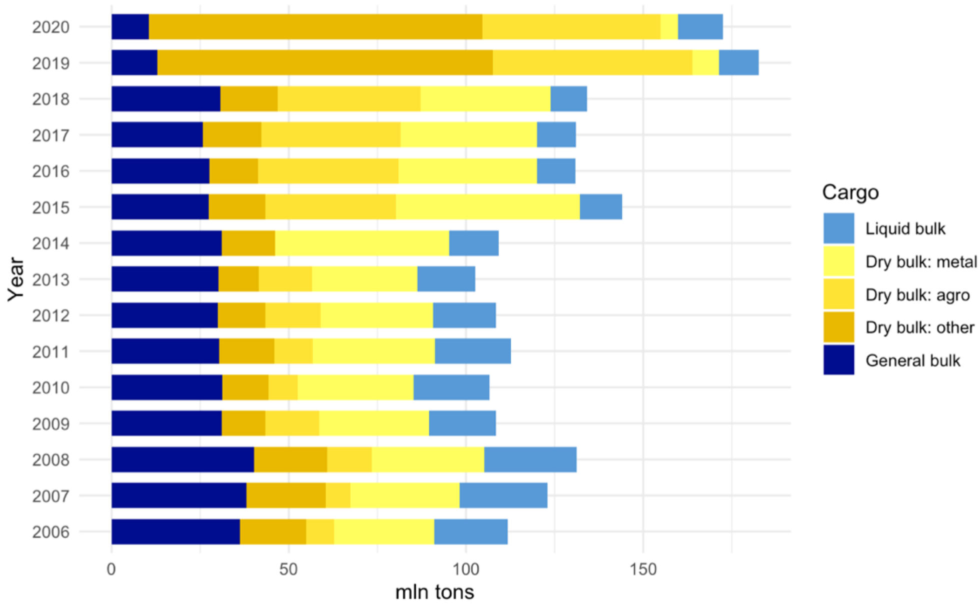

Figure 5. Annual ports' cargo traffic structure 2006-2020

Exorbitant port dues remain a sensitive topic in the industry. The port tariffs, which are comprised of seven types of dues (administrative, channel, ship, lighthouse, sanitary, mooring, and anchor tariffs), are established and regulated by the Ministry of Infrastructure and are paid to the USPA, except for administrative and lighthouse port tariffs, which are paid to the state enterprise "Derzhgidrographia" and the State Budget respectively. The burden of high port tariffs is carried by Ukrainian exporters and domestic producers, hamstring private sector development and impoverishing the country (OECD Investment Policy Reviews: Ukraine 2016). Noteworthy, USPA granted discounts for some ports: for Yalta port, the shipping tariff was reduced by 50%, and Yuzhniy port benefited from a 50% discount for all tariff types. Moreover, the recent decline in tariff rates by almost 20% in 2018 promised a slight improvement. This reduction was especially promising for ports with lengthy channels which lead to the gates, as in Mykolaiv port, defining significant cost reduction for utilization of port capacities. The dynamics is presented on the Figure 6.

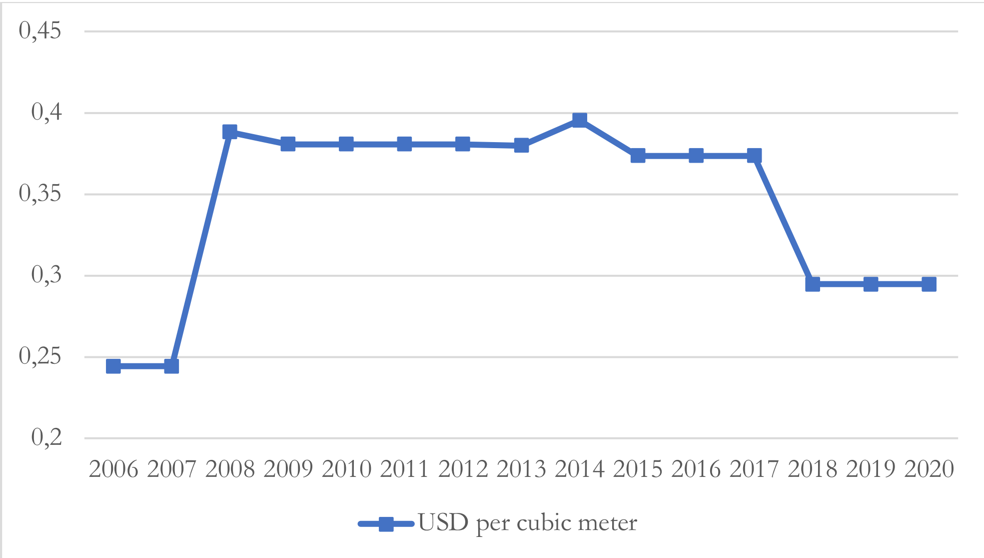

Figure 6. The dynamics of the average ports tariffs, 2006-2020

4.2 The description of variables for estimations

Following the suggestions of research of Yang and Yip (2019), input variables such as a number of berths, length and a maximum depth of berths, and total ports' area will be used as the inputs in port production. Labor input is omitted, as the quantity of labor is considered to be almost proportionally related to the number of equipment deployed (Cullinane and Song 2006). The dependent variable is going to be yearly volumes of cargo volumes at the port level as an output variable measured in tons. The descriptive statistics of ports' inputs are presented in Table 1. Clearly, we observe how different the port facilities are, with the number of berths in ports range from 1 to 47. The important development of this study is accounting for variations in port characteristics, namely for port deepening works and the launch of new berths, which has not been done previously. Ports of Mykolaiv, Odessa, Olvia, and Yuzhyi increased number of berths over the years, and all of them, as well as Chornomorsk, witnessed a depth increase since 2013.

Table 1. Descriptive statistics of physical characteristics of 13 Ukrainian ports, 2020

Variable	Mean	Min	25 percentile	75 percentile	Max
Total area	1555.14	44.96	704.20	2466.93	3706.00
Number of berths	19.15	1	11	23	50
Maximum depth	10.22	3	7.5	12.23	19

Apart from physical inputs, it is essential to include other contextual variables in the model, as the empirical literature suggests. The efficiency of seaports can vary over time to different extents, therefore the time trend variable is included. Moreover, the annexation of Crimea was a severe shock for the Ukrainian economy, inevitably affecting cargo traffic volumes in ports. To account for any regional differences, as for example, region transport connectivity or differences in economic production, we include region variable following the ideas of Chen, Chou and Hsieh (2018). The region variables are used in different ways for two methodologies: for SFA estimation we include region variables as inputs to the production function, while for alpha-score estimation we include them in the second stage of estimation as an explanatory variables of the efficiency score.

Specialization index is constructed similarly to Zghidi (2017), where it equals the sum of squared tonnage volumes of various commodities – t_i divided over the squared total volume of cargo:

$$Si = \frac{\sum_i t_i^2}{(\sum_i t_i)^2} \tag{6}$$

The index values range from 0 to 1, where zero value means absolute specialization and the unity determines the handling of highly diverse cargo. Figure 7 presents the juxtaposition of average ports' cargo volumes and an average port specialization index computed for 13 years. Easy to notice the pattern that implies that the largest ports are usually highly specialized, while the smallest ones process highly diverse cargo. This can be explained that in order to reduce vessel downtime, smaller ports seek orders for various types of cargo, while the largest ones are busy processing commodities of their primary interest, which defines port specialization.

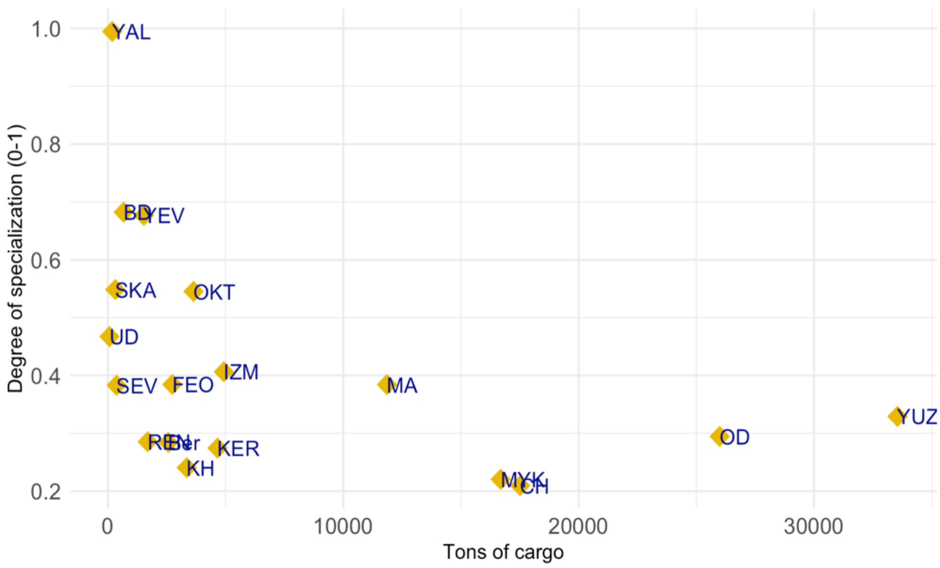

Figure 7. Average port cargo volumes and port specialization index

Addressing potential omitted variable bias, stemmed from lack of data about port infrastructure quality and land connectivity, we introduce infrastructure index, which is defined as the ratio of annual cargo volume to existing port capacity, which is predefined technical characteristic for each port taken from USPA register. For most observations it ranges from zero to one and gives insights on how well internal capacities are used, however it exceeds one if cargo volumes that year were above the limits of port capacity. Thus, the fluctuation of the infrastructure index over time would proxy improvements in technology, level of service which have been introduced in the ports. Thus, we would be able to capture some improvements that are indispensable part of efficiency.

Descriptive statistics for the cargo volumes and other than region factor and time trend variables are summarized in Table 2, with all 235 observations taken into consideration. The average specialization index equal to 0.41, showing that ports tend to incline towards cargo differentiation, and there are no observation with the indicator equal zero, signaling absolute specialization. The infrastructure index on average equals 0.43, implying there is a room for improvement in terms of how ports manage their existing facilities.

Table 2. Descriptive statistics for dependent and contextual variables

Variable	Mean	St. dev.	Min	Max
Annual cargo, thsd. tons	8163.12	11034.73	3800	61664.81
Port tariffs, USD/m^3	0.34	0.12	0.15	0.67
Specialization index	0.41	0.22	0.13	1.00
Infrastructure index	0.43	0.28	0.01	1.39

Chapter 5

ESTIMATION RESULTS

In this chapter, we will compare the efficiency estimates obtained from SFA and alpha-score methods and then proceed to explain the results for each method separately and compare the efficiency determinants in both cases. Let's consider first the ranking of efficiency estimates for 2020 and compare them with the ranking suggested by cargo volumes as Table 3 suggests.

Table 3. Ranking of SFA and order-α estimates and cargo volumes, 2020

Port	SFA score	Order-α score	Volume rank	SFA rank	Order-α rank
YUZ	1.00	1.00	1	1	1
MYK	0.90	0.90	2	3	2
CH	0.91	0.71	3	2	3
OD	0.68	0.68	4	4	4
MA	0.40	0.40	5	9	9
OKT	0.56	0.56	6	6	5
IZM	0.47	0.47	7	8	7
KH	0.67	0.45	8	5	8
Ber	0.48	0.48	9	7	6
REN	0.23	0.23	10	10	10
BD	0.06	0.06	11	12	12
UD	0.09	0.09	12	11	11
SKA	0.00	0.00	13	13	13

In the Table 3 we observe that ranking based on efficiency and cargo volumes coincide for the first and the last port in a row. Yuzhniy, which alone processes 39% of gross annual cargo in 2020, is ranked as the most efficient. Ports of Skadovsk and Bilhorod-Dnistrovskyi share the lowest efficiency scores. However, for Mariupol and Berdyansk, the difference between the two rankings becomes more pronounced. Mariupol, the 5th port by cargo volume, is ranked only 9th by the efficiency with an SFA score of 0.4, suggesting there is room for improvement. For Berdyansk port, SFA and order-α evaluate port performance as 0.48 score, but anyway rank it higher than the cargo volume ranking.

The ranking in 2020 contrasts with one in 2013 when Mariupol is estimated to be the most efficient, overperforming Yuzhniy, Odessa and Chornomorsk. The port of Mariupol served as a major gate for maritime trade through the Azov sea and had a constant flow of dry bulk cargo with metal commodities transported from the industrial areas in Eastern Ukraine before the political conflict with Russia in 2014 changed the status quo.

Table 4. Ranking of SFA and order-α estimates and cargo volumes, 2013

Port	SFA score	Order-α	Volume rank	SFA rank	Order-α rank
OD	0.67	0.67	1	4	4
YUZ	0.36	0.67	2	13	5
MA	0.84	0.84	3	1	2
CH	0.53	0.41	4	7	12
MYK	0.32	0.98	5	14	1
KH	0.68	0.47	6	3	11
REN	0.81	0.81	7	2	3
IZM	0.40	0.40	8	12	13
FEO	0.66	0.66	9	5	6
Ber	0.49	0.49	10	10	9
OKT	0.26	0.26	11	16	15
KER	0.28	0.28	12	15	14
YEV	0.48	0.48	13	11	10
BD	0.53	0.53	14	8	8
SKA	0.25	0.25	15	17	16
SEV	0.50	0.20	16	9	17
YAL	0.62	0.62	17	6	7
UD	0.15	0.15	18	18	18

Worth mentioning, the mean efficiency score of the ports fluctuated over time: from 0.67 in 2006 to 0.48 in 2013 and 0.5 in 2020 based on SFA estimates. Figure 8 shows the dynamics of the mean score across all the ports. After its peak in 2008, the efficiency of ports declined, so as the total cargo volumes as Figure 5 previously explained. The great increase in efficiency came in 2013, which can be attributed to the results of the successful ports reform. However, the turbulence of political upheaval in 2014-2015 in Ukraine and the annexation of Crimean ports (which are excluded from the sample starting from 2014) resulted in mean efficiency drop which reached the floor in 2018. Overall, the graph clearly exhibits a declining trend: despite some specific ports improved their performance, the overall state of industry is rather worrisome and efficiency matters have to be taken into consideration in the future.

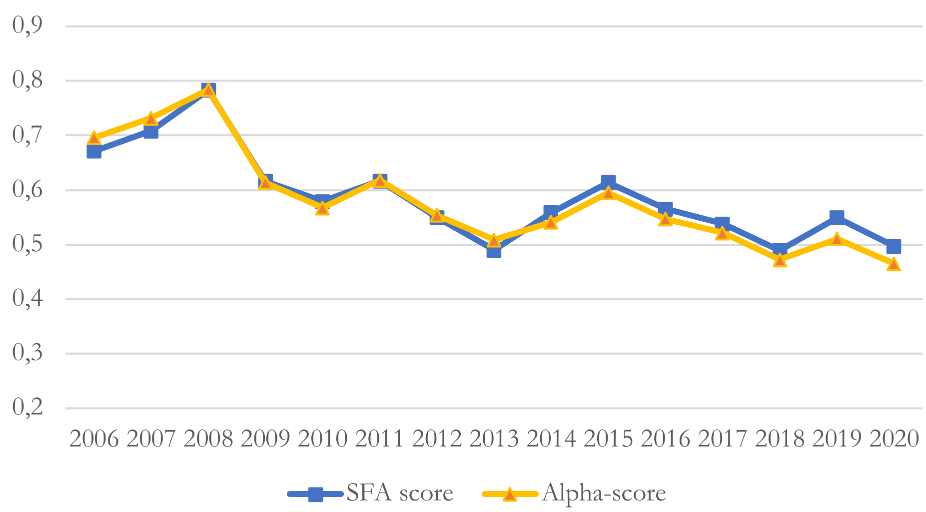

Figure 8. Mean efficiency scores dynamics, 2006-2020

Let's now consider the output of SFA estimation and discuss the determinants of the efficiency score according to this method. Table 5 with the result for SFA methodology consists of two parts: the "frontier" part presents the estimates of the production function's inputs, and the "usigma" part explains the determinants of the inefficiency, as modeled by the equation (2). Total area and port depth variables are positively related to the cargo volumes, though the number of berths is related negatively, suggesting that construction of new berths does not necessarily lead to cargo volume improvements. Odessa region was selected as a base region for input in the production frontier. Compared to the Odessa region, Azov and Dunai regions enjoy some additional benefits in cargo handling stemming from their location's peculiarities, while for Crimea region and the ports in Dnipro mouth this relation is inverse. As for factors augmenting the inefficiency, the model captures the significant impact of port tariffs, promising a 0.098 inefficiency increase for every 10% increase in tariffs rate. In contrast, improvement in infrastructure, reflected by the increase in the infrastructure index, significantly curtails the inefficiency. The 10% increase in the infrastructure index is associated with a 0.14 decrease in inefficiency score. Thus, this factor can be considered as a key performance driver. Time trend and specialization index are considered insignificant, suggesting there is no sound inefficiency trend across the timespan and the cargo choice has no effect on port performance. In alternative specification, we also tested interaction terms of time trend with tariffs and dummy variables to separate the effect of the 2013 reform. They were also estimated as insignificant. The model also suggests that the port capacity on inefficiency does not have any effect on port's performance either.

Table 5. Results of SFA efficiency estimates

Variable	Estimate	
Frontier		
ln(Total area)	0.78	***
	(0.00)	
ln(Number of berths)	-0.73	***
	(0.00)	
log(Maximum depth)	1.71	***
	(0.00)	
Azov Region	0.91	***
	(0.00)	
Crimea Region	-0.24	***
	(0.00)	
Dnipro mouth Region	-0.19	***
	(0.00)	
Dunai Region	0.70	***
	(0.00)	
Usigma		
Year	0.01	
	(0.02)	
ln(Tariffs)	0.98	***
	(0.28)	
ln(Infrastructure index)	-1.44	***
	(0.17)	
ln(Specialization index)	-0.01	
	(0.22)	
ln(Port capacity)	-0.07	
	(0.07)	
Constant	0.64	
	(42.07)	
Vsigma		
Constant	-31.77	
	(195.38)	
E(sigma_u)	1.02	
sigma_v	0.00	
	(0.00)	

Note: Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '. 235 observations.

The results of the second stage for the truncated regression of efficiency determinants on order-α efficiency score are presented in Table 6. Aligned with SFA results, we observe a negative effect of port tariffs on efficiency. Both methods give quite similar results in magnitude as well. The coefficient suggests that 10% increase in port tariffs will result in a loss of 0.01 efficiency score. The infrastructure index also shows positive impact on efficiency with 10% index increase associated with 0.027 efficiency score gain. In contrast, here we observe a negative time trend, showing that each year on average the efficiency declined across all the ports, which is supported by the dynamics presented in Figure 8. As for the port capacity, the results contrast with SFA, where the variable was insignificant. Here we see a positive relation between port size and efficiency, suggesting that 10% capacity increase on average results in increased port efficiency by 0.006. However, this effect is almost four times lower that the one of infrastructure index improvements. Similarly to the previous model, we used Odessa region as a base level for the region variable. Alpha-score estimation founds no additional improvements in efficiency based on some regional characteristics, except for Crimean ports.

Despite some discrepancies in coefficient magnitudes, which can be easily explained by fundamental differences in methodology, the estimates for both methods exhibit a high correlation with each other of 0.78. Moreover, the directions of the effects in two model are consistent with exceptions for port capacity variable and region dummies, which are used in different ways in SFA and alpha-score respectively. Both models highlight the negative effect of high port tariffs and a positive impact of infrastructure development on port performance, which suggest useful policy implications for port authorities.

Table 6. Results of truncated regression on order-α efficiency estimates

Order-α efficiency score	Estimate	
Constant	0.32	**
	(0.10)	
Azov Region	0.00	
	(0.03)	
Crimea Region	0.22	***
	(0.04)	
Dnipro mouth Region	0.04	
	(0.03)	
Dunai Region	0.01	
	(0.03)	
Year	-0.01	***
	(0.00)	
ln(Tariffs)	-0.10	**
	(0.04)	
ln(Infrastructure index)	0.27	***
	(0.01)	
ln(Specialization index)	0.02	
	(0.02)	
ln(Port capacity)	0.06	***
	(0.01)	
sigma	0.15	***
	(0.01)	

Note: Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '. 235 observations.

Chapter 6

CONCLUSIONS AND POLICY RECOMENDATIONS

The two methodologies applied enable us to make insightful conclusions on the study's research question of what determines port efficiency in Ukraine. Let us then turn back to the study's hypothesis discussed in Chapter 1.

The first hypothesis questions whether port dimensions positively affects the efficiency score. Indeed, the second-stage regression proved the efficiency increase as the port augments their capacity. It explains the fact that port with the highest port capacity, as Chornomorsk, Yuzhnyi, and Odesa, exhibit high efficiency scores in 2020 respectively. However, it is the maximum depth of ports that most affects the total cargo handlings. The second hypothesis about the negative impact of port tariffs on efficiency is also proven to be true. According to non-parametric order-α efficiency frontier, the efficiency score worsens by 0.01 for every 10% increase in tariffs. The third hypothesis about the role of specialization in port efficiency remains ambivalent, as no significant impact of specialization on efficiency found so far. Moreover, instead of specialization index, the study also tested other variables, like share of dry bulk, liquid bulk or general bulk, to examine the effect of cargo type on the efficiency. Nonetheless, no significant effect was found either.

Apart from that, we managed to identity the most efficient ports in Ukraine throughout the last 14 years, contributing to the monitoring efforts in port industry. Yuzhnyi, Mykolaiv, Odessa and Chornomorsk the leaders in terms of efficiency, however ports as Mariupol and Berdyansk lost several positions in rank since 2006 and now have the 9th and 12th position in the rank respectively.

As a final remark, it is instrumental to suggest the list of further development on the topic of this study. As mentioned before, infrastructure index plays a crucial role in determining port efficiency, however with appropriate data it will be beneficial to decipher this index controlling for different components of infrastructure in ports, such as technology level, transportation connectivity, level of automation etc. Additionally, as some ports will be used under concession agreement, it is important to include the variable to control for concession, as it can play the role in increased efficiencies.

To conclude, the recommendation list for policy-makers who seek to increase port efficiency contains three key messages. First of all, one has to initiate and support the discussion around continuing port tariffs reduction. Secondly, the most important efficiency-improving factor is the infrastructure, technology and level of services in the port. And lastly, the study has shown that projects aimed at port capacity increase on average results in efficiency growth, therefore has to be considered by the port administrations.

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