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Competition on the Railway Market in a Segment of Public Service Obligations in Terms of Effectiveness: Study in V4 Countries

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Abstract

Since the introduction of new European Union legislation seeking to establish a single European railway area and increase the railway sector's competitiveness, competition has also become a reality in this, until then, monopoly market. In addition to allowing open access to the railway market with freight and passenger services, competition in the regulated part of the market has been increasing, specifically in the segment of public passenger transport services. Public tendering for providing public services has increased the quality of services for passengers and contracting authorities; however, the question remains whether this model of awarding these services is also effective from a socioeconomic viewpoint. This study focused on evaluating contracting authorities of public services in the Visegrád-4 countries regarding public spending effectiveness. Based on the chosen model inputs and outputs related to performance and value indicators of public service contracts, we calculate individual contracting authorities' relative effectiveness using nonparametric data envelopment analysis (DEA) models. We subsequently tested assumptions of the difference in effectiveness according to awarding services, individual countries or ownership of railway undertakings. We came to the conclusion that it is not possible to confirm that public tenders in V4 countries significantly increased the effectiveness of public spending in comparison with direct awards or other ways of awarding PSO. Discussions on the main results and research limitations are also part of this paper.

Keywords: railway market, competition, public service obligation, compensation, effectiveness
JEL Classification: R40

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1. INTRODUCTION

Inefficient governance and the financial problems of unitary railways in European countries resulted in the search for a solution to reform the existing railway system in the 1990s. The basis for implementing reforms in the European railway area was the structural reforms of the previously unitary railway undertakings—a vertical and horizontal separation of the infrastructure management and operating passenger and freight railway transport (Council Directive 91/440/EEC, 1991). The European Commission (EC) issued sets of Directives and Regulations (railway packages) for the planned opening of the railway market in the European Union (EU). Recently, four railway packages have entered into force.

The fourth railway package entered into force in June 2016 and is a set of legal documents designed to complete the single market for rail services. Its overarching goal is to revitalise the railway sector and make it more efficient and, thus, competitive with other transportation modes based on the mandatory public tenders for operating services under public interest (public service obligations; PSOs). The current European legislation defines PSO as a 'requirement defined or determined by a competent authority in order to ensure public passenger transport services in the general interest that an operator, if it were considering its own commercial interests, would not assume or would not assume to the same extent or under the same conditions without reward' (Regulation (EC) No 1370, 2007).

This article's structure comprises a theoretical background related to railway market deregulation based on a literature review. We introduce the data from Visegrád-4 (V4) countries, which have been evaluated using the described methodology. After the evaluation, we discuss our empirical results and compare them with previous studies.

2. THEORETICAL BACKGROUND

This study divides the competition in the railway market into three categories. Chronologically, the first is the EU railway reform process and the legal framework. Directly related to this, we discuss the issue of liberating and deregulating the railway market, focusing on the railway market with passenger transport services. The last and most important topic is PSO development in the EU and experiences with public tenders for providing these services. Several authors have discussed these topics, drawing attention to transport services and economics.

De Francesco (2019) analysed 52 evaluation studies on EU railway policy. Asmild et al. (2008) considered railway operations in 23 European countries at the beginning of the 21st century and analysed whether railway reform initiatives improved the railway sector's efficiency in the EU. This article provides empirical results, proposing that vertically separating the infrastructure management and operation of transport services is crucial for improving the efficiency of all relevant costs of the railway undertaking. Holvad (2009) provided an overview of the most important railway reforms in the EU. He focused on the background of the reform process, the legislation, EC Directives and finally on implementing these EC Directives in the member states. Van de Velde (2015) evaluated this issue from the perspective of unbundling and the need for coordination. Nash (2008) monitored the entire railway reform process in the EU since the separation of infrastructure from operations in Sweden. He concluded that countries that have entirely separated the infrastructure from operating transport services had been the most successful in introducing the competition, but they also increased transaction costs. Stojić et al. (2009) presented a model of railway reform evaluation using fuzzy logic with several inputs, such as reform preparation, criteria fulfilment, and competitiveness level in the railway market.

Several authors have addressed railway reform development in individual member states.

Alexanderson & Rigas (2013) analysed rail liberalisation in Sweden to show the impact of market opening and reform policy. Andersson & Pettersson (2015) described the history of Swedish railway policy from 1902 to 1967, focusing on the conflict between private interests and the state. Engartner (2010) evaluated the German railway reform and focused on the controversial traffic policy decisions that aimed to increase the share value on the stock market. Giannopoulos & Giannakos (2007) presented the railway restructuring process in Greece. The authors critically evaluated the Greek railway reform process and presented alternative organisational structures for the new situation in the market. Tóth (2019) addressed the railway development in the Central Europe countries (V4 Group). They elaborated a detailed analysis describing the number of railway undertakings in V4 countries, the major international railway organisations, and the impact of EU institutions on railway projects in the V4 Group. The author addressed Central and East European railway integration through spillovers. Grushevska et al. (2016) elaborated the case of Ukrainian railways. The authors compared the classical railway reform models in the West and Central Europe countries with the railway reform model in other parts of Europe, especially in Ukraine. They analysed the process of institutional reform in the country and its effectiveness in developing Ukrainian railways.

One of the most discussed topics related to the EU railway reforms is opening the railway market for competition. This study focuses on the passenger railway transport market's competitive environment. Gutiérrez-Hita & Ruiz-Rua (2019) analysed several paths toward railway market liberalisation, divided them into monopoly and oligopoly models and discussed the regulatory measures. Ait Ali & Eliasson (2021) reviewed market organisation and capacity allocation related to the European railway deregulation. The authors focused on the vertical separation of the infrastructure management and transport service operation in the context of rail capacity allocation and track access charges. They concluded that only a few countries have so far allocated the rail capacity transparently. Cantos et al. (2012) evaluated the European railway market deregulation using various approaches. The authors presented the market effectiveness level in the member states using the nonparametric data envelopment analysis (DEA) and stochastic frontier analysis models. Álvarez-San Jaime et al. (2015), Bailo & Martínez (2021), Bougna & Crozet (2016), Beria et al. (2012), De Francesco & Castro (2016), Desmaris (2014), Dias & Trindade (2016), Hilal (2008), Charanwanitwong & Fraszcyk (2018), Lerida-Navarro et al. (2019), Majerčák & Majerčáková (2013), Mężyk & Zagożdżon (2019), Nash (2008), Nash et al. (2019), Tomeš et al. (2014), Xiao & Wang (2011) directly addressed deregulating the passenger transport market. Table 1 presents a detailed overview of their studies and papers, grouped into clusters according to the areas and countries of interest.

Tab. 1 – Overview of studies related to deregulating railway passenger markets in Europe. Source: own research

Authors	Area	Authors	Area
Alexanderson & Rigas	Sweden	Hilal	EU countries
Álvarez-San Jaime et al.	Spain	Charanwanitwong & Fraszczyk	EU countries, Thailand
Bailo & Martínez	Spain	Lerida-Navarro et al.	EU countries

Beria et al.	EU countries	Majerčák & Majerčáková	EU countries
Bougna & Crozet	EU countries	Mężyk & Zagożdżon	EU countries
De Francesco, Castro	EU countries	Nash	EU countries
Desmaris	Switzerland	Nash et al.	EU countries
Dias & Trindade	EU countries	Tomeš et al.	Czech Republic
Xiao & Wang	EU countries		

Very few studies were found on the competition for the market, that is, public tendering of the PSO. Therefore, it is even more crucial to address this issue that most member states struggle with. Gašparík et al. (2017) addressed the competitive tendering in rail passenger transport in long-distance services in the EU member states. They subsequently proposed the general methodology for tendering these services based on the current legislative framework and previous experiences of member states with public tenders in rail passenger transport (Gašparík et al., 2018). Maczkovics (2017) proposed a preview of the fourth railway package. The author primarily focused on the market pillar, divided into open-access services and public tendering for services under PSO. Herrgott (2015) evaluated the role of public transport regional authorities in France. Kvizda (2013) proposed that solving the competition problem in the railway market raises the question of whether market regulation (especially PSO) is not a better model for future success. The topic of contracting out public transport services and rail subsidisation in the EU has been researched by authors such as Dementiev (2018) and Crössmann & Mouse (2015).

3. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

This article evaluates the effectiveness of PSO in railway transport on the public budget in the V4 Group countries (Slovak Republic, Czech Republic, Poland and Hungary) based on the detailed analysis of PSO contracts and the development of subsidies for these services. This aim contains the following sub-objectives:

- analysing critical indicators of the railway market in individual countries,
- design the dataset of PSO contracts by state and regional authorities,
- analysing performance and value indicator time series,
- determining a hypothesis,
- composing the model,
- hypothesis testing and
- interpreting the model.

3.1. Methodology

We determined three critical indicators of the railway market's performance in PSO for our analysis and evaluation. Operational performance in passenger railway transport expresses the extent of railway traffic in a defined area during a defined period. The unit of operational performance is train-kilometre (tkm), and this performance indicator can be calculated as follows:

$$P_o = \sum_{i=1}^{n} n * L, \quad (1)$$

where P_o is the operational performance in tkm, n represents the number of trains in a defined area during a defined period (day or year), and L is the train route length in kilometres (Dolinayová et al., 2016).

Transport performance in passenger railway transport represents the volume of transported passengers multiplied by the average travel distance in a defined area during a defined period. The unit of transport performance is passenger-kilometre (pkm).

$$P_T = \sum_{i=1}^{n} n_p * \emptyset L, \quad (2)$$

where P_T is the operational performance in pkm, n_p represents the number of passengers transported in a defined area during a defined period (day or year) and ØL is passengers' average travel distance (Dolinayová et al., 2016).

The compensation amount represents the PSO value indicator of public spending. This compensation depends on the costs incurred by the railway for operating the PSO. Based on the PSO contract, economically justified costs are paid from the state budget (Dolinayová et al., 2022). In determining the compensation amount for provable loss for providing services under a contract, the compensation cannot exceed the net financial impact corresponding to the sum of positive or negative effects (Regulation No 1370/2007 of European Parliament and of the Council, 2007). The formula for determining the compensation amount from the applicable European legislation is

Compensation (NFI)=EJC-PFI-R+P, (3)

where NFI represents the net financial impact (compensation), EJC represents economically justified costs, PFI represents the positive financial results created by PSO, R means revenues from transport services and P represents the railway undertaking's reasonable profit (Regulation No 1370/2007 of European Parliament and of the Council, 2007).

We evaluated the public service efficiency in railway transport using nonparametric DEA models due to breaches of the data normality condition and a smaller data sample. DEA models evaluate the relative efficiency of a specific set of units, indicating that extending the file by another unit changes the effective limit estimated from a specific model. Consider a set of homogeneous decision units U1, U2, …, Un. When evaluating the efficiency of these units, we consider r outputs and m inputs. Let X = {xij, i = 1, 2, …, m, j = 1, 2, …, n} be an input matrix and similarly, Y = {ykj, k = 1, 2, …, r, j = 1, 2, …, n} be an output matrix. The efficiency of the unit Uq can be expressed as follows:

$$\frac{\sum_{k=1}^{r} u_k y_{kq}}{\sum_{i=1}^{m} v_i x_{iq}}, \quad (4)$$

where v_i, i = 1, 2, …, m are the weights assigned to the i input and u_k, k = 1, 2 …, r are the weights assigned to the k output. It is the weighted sum of outputs divided by the weighted sum of inputs of unit Uq (Jablonský & Dlouhý, 2004).

Radial DEA models are based on radially measuring the distance of a production unit from the effective limit (Kočišová, 2012). Ordinary models provide a measure of efficiency and information on how the unit must improve its behaviour to reach the effective frontier. The two basic DEA models include the Charnes–Cooper–Rhodes (CCR) model, calculated from the condition of constant returns to scale (CRS), and the Banker–Charnes–Cooper (BCC) model adapted to assume the variable returns to scale (VRS). The resulting values of the relative effectiveness of individual decision-making units (DMUs) are calculated using linear programming (Jablonský & Dlouhý, 2004).

3.2. Analysing critical indicators

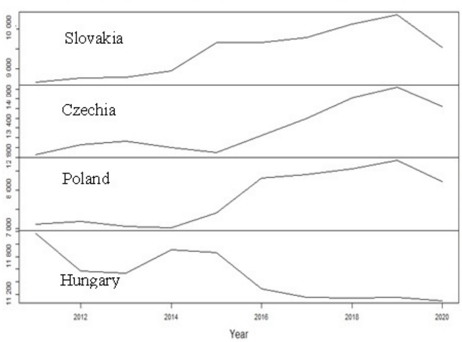
The study used the V4 countries (Slovakia, Czech Republic, Poland and Hungary) as the research focus. We collected data on the railway market, especially PSO services, and focused on the performance indicators and public spending for subsided railway passenger services. Data sources are the official documents of state or regional authorities (summary report on PSO) published on their websites or collected individually from the official request of the competent authorities. At the level of state institutions, we collected data primarily from the Ministry of Transport (Slovakia, Czech Republic) and the Ministry of Infrastructure (Poland and Hungary). The self-governing regional offices of the Czech Republic regions and voivodship offices of regions in Poland provided the regional data. Data on the number of passengers transported were obtained from publicly available statistical databases and yearbooks. We monitored all indicators as a time series starting in 2011 and ending in 2020, with annual frequency. This period was chosen according to the EU legal framework development, and the issue of the third and fourth railway packages focused on the competition in the railway passenger market.

For the initial comparison of the railway market, we focused first on railway reform development in individual V4 countries, including the railway undertakings in the rail passenger market and new entrants in open-access and PSO services. For the quantitative analysis, we chose the time series of operational performance in tkm related to the 1 km of operated network in the country due to the greater relevance of the comparison, and the transport performance in pkm related to the operational performance in the country. Table 2 summarises the railway reform overview, vertical and horizontal structures of railway undertakings and new undertakings entering the market. For vertical (infrastructure management vs. provision of transport services) and horizontal (passenger transport vs. freight transport services) structures, the current framework divides between the separated (institutional division of railway undertakings) and integrated (only accounting division) models. According to the territory, significant differences exist in contract awarding used in individual countries. Overall, we divide between the centralised model, with one responsible authority, usually at the state level (Slovakia, Hungary), and the decentralised model, with more responsible authorities, at the state for long-distance services and regional level for regional services (Czech Republic, Poland). Two models exist for operating the competition in the railway market. The first is the open-access model, where railway undertakings provide their services commercially. The second model is public tendering for PSO services, meaning competition in the regulated market. Open-access services are operated in most V4 countries, except for Hungary, where it was introduced only at the legal level. The Czech Republic is the only country that has successfully awarded part of the public services using public tendering for PSO services. However, using tenders depends on the specific region and the competent authority.

Tab. 2 – Overview of current situation after railway reforms in V4 countries. Source: own research

Country	Vertical structure	Horizontal structure	Open access		Public tendering		contract awarding
			incumbent	private RU	incumbent	private RU	
Slovakia	separated	separated	de facto	de facto	de iure	de iure	centralised
Czech Rep.	separated	integrated	de facto	de facto	de facto	de facto	decentralised
Poland	integrated	integrated	de facto	de facto	de iure	de iure	decentralised
Hungary	integrated	separated	de iure	de iure	-	-	centralised

The trend of operational performance (Figure 1a) calculated per 1 km of the operated network has had similar development in Slovakia, the Czech Republic and Poland. This indicator has been increasing since 2014–2015, with a slight decline in 2020 due to the pandemic. However, the development in Hungary has been steadily decreasing since 2015, and the deviation during the pandemic has been milder.



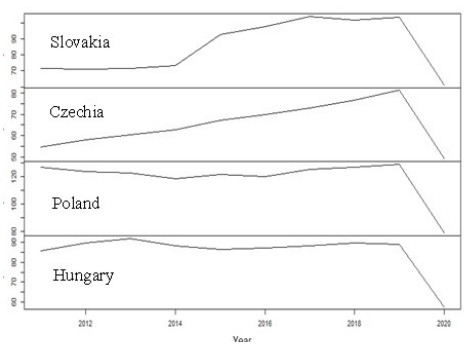


Fig. 1a – Development of operational performance in thsnd/tkm related to 1 km of operated network. Source: own research

Fig. 1b – Development of transport performance in mil/pkm calculated per 1 tkm. Source: own research

Figure 1b shows that the development of transport performance in pkm calculated per tkm in each country is similar. The continuous increase or stagnation occurred until 2019, followed by a sharp decline in 2020 due to the mobility restrictions and lockdowns during the COVID-19 pandemic. The transport performance volume in 2020 is the lowest in the last decade. Slovakia showed unexpected growth in pkm in 2015 due to the government introducing free transport for children, students and the elderly as part of social welfare packages.

There is a significant difference in compensation between countries using the centralised model of awarding PSO (Slovakia and Hungary) and those using the decentralised model (Czech Republic and Poland). This trend has been noticed throughout the time series development from 2011 to 2020. To represent the current situation, 2019 was chosen due to apparent deviations in values since 2020 caused by the COVID-19 pandemic.

3.3. Model determination

Because we obtained data that did not behave according to the normal distribution, we proceeded to the evaluation using nonparametric methods. We used input-oriented radial DEA models to evaluate the PSO efficiency in public finance. The first crucial step is to determine relevant inputs and outputs of the DEA model considering our hypothesis. Each contracting authority across the V4 countries represents the DMUs. We used 32 DMUs, of which 15 belong to the Czech Republic and 15 to Poland. Slovakia and Hungary use the centralised PSO awarding model, each representing one DMU. All models were developed using data from the base period of 2019.

Inputs to our model have been determined as performance indicators related to PSO, specifically,

- X1 - operational performance (mil. tkm),
- X2 - length of the operated railway network (km),
- X3 - number of passengers transported (mil. passengers),
- X4 -population (mil. inhabitants).

There might be a higher correlation rate between individual inputs, especially between the operational performance and the network length and analogically between the population and number of passengers. Therefore, we also calculated the relative indicators, considering socio-economics aspects in the individual countries or regions, which were as follows:

- X5 - operational performance expressed as a share per km of the operated network (tkm/km),
- X6 - number of passengers transported expressed as a share per inhabitant.

To confirm the relevancy of each input for the model results, we calculated the Pearson correlation coefficients (Table 3), confirming a high correlation between the operational performance in tkm and other inputs (X2, X3, X5). We also confirmed that these results are statistically significant with p-value lower than 0.05. There is also a high positive correlation approaching 1.0 between the individual inputs representing the area's socioeconomic conditions. Therefore, we included the absolute number of passengers transported, the relative number of passengers expressed as a share per inhabitant and the operational performance expressed as a share per km of the operated network as inputs in the resulting model.

Tab. 3 – Pearson correlation coefficients between the individual model inputs. Source: own research

	X1	X2	X3	X4	X5	X6
X1	1	0.859	0.761	0.129	0.665	0.155
p-value	0.000	0.000	0.000	0.482	0.000	0.397
X2	0.859	1	0.509	0.248	0.434	0.444
p-value	0.000	0.000	0.003	0.171	0.013	0.011
X3	0.761	0.509	1	-0.184	0.969	-0.158
p-value	0.000	0.003	0.000	0.313	0.000	0.388

X4	0.129	0.248	-0.184	1	-0.168	0.566
p-value	0.482	0.171	0.313	0.000	0.358	0.001
X5	0.665	0.434	0.969	-0.168	1	-0.170
p-value	0.000	0.013	0.000	0.358	0.000	0.352
X6	0.155	0.444	-0.158	0.566	-0.170	1

We analogically analysed the correlation between potential outputs in our model. The public spending for PSO in each region or state represents the outputs, calculated relative to the operational and transport performance for a more relevant comparison of the data:

- Y1 - total compensation amount (mil. PPS),
- Y2 - compensation amount per unit of operational performance (PPS/tkm),
- Y3 - compensation amount per unit of transport performance (PPS/passenger).

Table 4 shows no significant correlation between the individual outputs; however, we omitted the indicator of the total compensation amount from the model, as it is more accurately expressed as performance units. This step is also supported by the fact that the low correlation rate was not statistically significant ($p>0.05$).

Tab. 4 – Pearson correlation coefficients between the individual model outputs. Source: own research

	Y1	Y2	Y3
Y1	1.00	0.28	-0.05
p-value	0.000	0.121	0.786
Y2	0.28	1.00	0.16
p-value	0.279	0.000	0.382
Y3	-0.05	0.16	1.00

The Annex summarises the model inputs and outputs for each contracting authority in the V4 countries. Based on the model and this study's objectives, we established these hypotheses, which will be the subjects of further research. The null hypotheses are set as follows:

Hypothesis A: There is not a statistically significant difference in the relative effectiveness of contracting authorities using the centralised model of awarding PSO and those using the decentralised model.

Hypothesis B: There is not a statistically significant difference in the relative effectiveness of contracting authorities based on how they award PSO (direct award or public tendering).

Hypothesis C: There is not a statistically significant difference in the relative effectiveness of contracting authorities between individual countries.

Hypothesis D: There is not a statistically significant difference in the relative effectiveness of contracting authorities based on the ownership of railway undertakings providing PSO (state or private).

4. RESULTS AND DISCUSSION

We evaluated the effectiveness of PSO based on the chosen inputs and outputs using the DEA input-oriented CRS and VRS models. The models' composition and evaluation and the hypothesis testing were conducted in the software environment of R Studio using the R language algorithm and Microsoft Office spreadsheets. We calculated the relative effectiveness of individual contracting authorities using the developed models. For DEA model composition and calculation, we used the lp library of R, with codes proposed by Pessanha et al. (2013). Using the CRS model, three contracting authorities were marked as effective compared to the set of all DMUs. Using the VRS model, we considered seven contracting authorities as effective. Table 5 shows the summary statistics (number of effective DMUs, average efficiency rate, median, minimum, maximum and dispersion and standard deviation) of each model's efficiency rates in total and by individual country. The lowest values were calculated for countries using the centralised model of awarding PSO (Hungary and Slovakia). However, considering the VRS model, Slovakia has been evaluated at the efficiency frontier. Overall, the efficiency rate is only approximately 1.22% higher in the VRS model than in CRS. Efficient DMUs, according to the CRS model, also achieve the efficiency frontier in the VRS model, and higher relative efficiency rates are achieved in the VRS model.

Tab. 5 – Results of DEA models–summary statistics. Source: own research

	eff DMU	average	median	min	disp	stand_dev
CRS	3	0.50	0.38	0.15	0.08	0.27
VRS	7	0.61	0.52	0.21	0.08	0.29
CZE_CRS	1	0.48	0.41	0.16	0.06	0.24
CZE_VRS	3	0.58	0.47	0.21	0.08	0.28
PL_CRS	2	0.55	0.42	0.15	0.09	0.31
PL_VRS	3	0.64	0.55	0.22	0.08	0.28
SR_CRS	0	0.31	0.31	0.31	0.00	-
SR_VRS	1	1.00	1.00	1.00	0.00	-
HU_CRS	0	0.19	0.19	0.19	0.00	-
HU_VRS	0	0.22	0.22	0.22	0.00	-

Note: CZE–Czech Republic; PL–Poland; SR–Slovak Republic; HU –Hungary

Figure 2 graphically compares each contracting authority's relative efficiency rates within V4 countries, including the CRS and VRS models. In most cases, the difference in efficiency rates between these two models is minimal. Still, there are exceptions where a significantly higher value is achieved (Slovakia, Stredočeský region and Praha city region). All concluded PSO using direct award and show higher operational performance. Next, we divided the relative efficiency rates of contracting authorities into different groups according to our research objectives and hypotheses established in the previous chapter. For hypothesis testing, we used a nonparametric Mann–Whitney test for independent samples because of the smaller data sample, and their distribution does not follow the standard curve. We divided individual contracting authorities into different groups, according to the statements in the previous chapter.

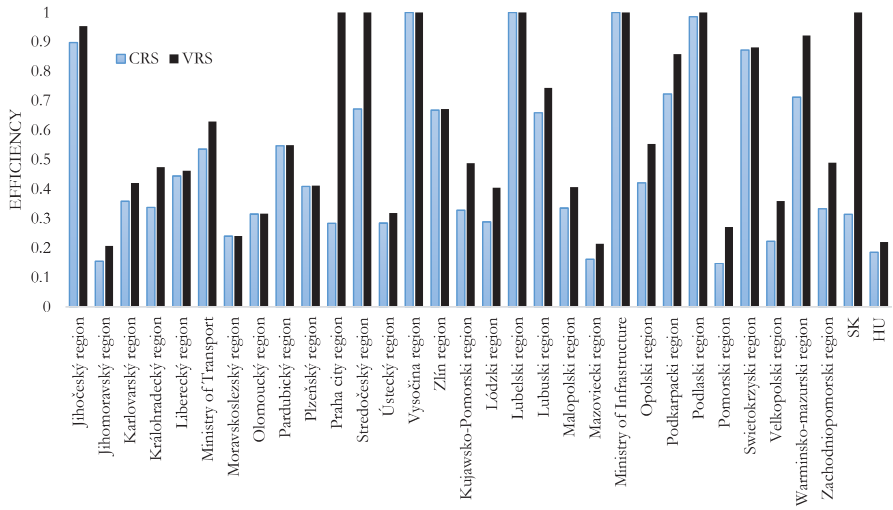


Fig. 2 – Graphical comparison of effectiveness rates using different models. Source: own research

Table 6 presents each group's summary statistics according to the hypothesis and the DEA model. Only a slight difference occurs between the centralised and decentralised models of PSO ordering regarding the average amount of relative effectiveness in the VRS model. The CRS model shows a higher difference favouring the decentralised model. The CRS model shows a larger deviation in averages when comparing the PSO to the ownership of railway undertakings. The variability of averages and medians between individual groups is higher for the VRS model (relative effectiveness rates higher than 50%). The direct award with public tendering comparison showed higher average effectiveness rates for those contracting authorities using only direct awarding of PSO.

Tab. 6 – Summary statistics by groups and DEA model. Source: own research

model	group 1	mean	median	group 2	mean	median
CRS	centralized	0.2501	0.2501	decentralized	0.5114	0.4152
	direct award	0.5008	0.35	public tender	0.4788	0.475
	Czech Republic	0.4768	0.4093	Poland	0.5461	0.4212
	incumbent	0.5787	0.5467	private RU	0.4115	0.3368
VRS	centralized	0.61	0.61	decentralized	0.6083	0.52
	direct award	0.6421	0.52	public tender	0.5075	0.48
	Czech Republic	0.5767	0.47	Poland	0.64	0.55
	incumbent	0.6944	0.87	private RU	0.5225	0.465

Table 7 summarises the Mann–Whitney test statistic results for each pair of determined groups. Based only on these results and p-values, we cannot reject the null hypothesis of no statistically significant difference between individual groups on the significance level of 0.05. Therefore, we cannot confirm visible differences in the public spending efficiency of contracting authorities according to how they contract PSO (hypotheses A, B and D). We expected minimal differences between individual countries without considering the model of awarding services, confirmed in this case due to the impossibility of rejecting the null hypothesis related to hypothesis C, with 95% probability.

Tab. 7 – Mann–Whitney test statistics by individual hypothesis and models. Source: own research

model	group 1	group 2	W	p-value	result
CRS	centralised	decentralised	11	0.1497	cannot reject H0
	direct award	public tender	94.5	0.9653	cannot reject H0
	Czech Republic	Poland	103	0.7088	cannot reject H0
	incumbent	private RU	165	0.1688	cannot reject H0
VRS	centralised	decentralised	28.5	0.9376	cannot reject H0
	direct award	public tender	69.5	0.255	cannot reject H0
	Czech Republic	Poland	100	0.617	cannot reject H0
	incumbent	private RU	166	0.1551	cannot reject H0

Discussing and comparing our results with other studies mentioned in the theoretical background of this paper, we brought a new perspective regarding competition in public services in passenger rail transport. While Asmild et al. (2009), Holvad (2009) and van de Velde (2015) focused on the railway sector's performance and the impact of structural reforms, other authors addressed the issue of the competition in the railway market, focusing on open access, e.g., Álvarez-San Jaime et al. (2015), Desmaris (2014), Nash et al. (2019), Tomeš et al. (2014) and Xiao & Wang (2011). We specifically addressed the competition for the regulated market, which has the largest share of performances in passenger rail transport. Kvizda (2013) proposed that the market competition model is more appropriate than open access. Garparík et al. (2019) focused on the conditions of public tenders introduced in EU countries and proposed optimising tender conditions to protect them from failure. These are critical aspects that we followed up on and needed for the future complex evaluation of the PSO sector. From the chosen methodology's view, several authors in this research field worked with nonparametric efficiency evaluation methods. A significant difference in our study is represented using inputs and outputs focused on public interest and spending efficiency.

5. CONCLUSIONS

Competition in the railway market, especially public services, is a recent topic. Several studies based on the market practice have defined several benefits and disadvantages of individual competition models; therefore, contracting authorities face a challenging decision about how to go in this field—most regard evaluating the effects crucial, especially from the public spending viewpoint. There is also increasing pressure on the quality of these services, which might conflict with the intention of financial efficiency. This study evaluated the PSO effectiveness in individual V4 countries based on determined inputs and outputs considering the nature and value criteria of PSO contracts. The study focused on the impact of the various ways of awarding PSO and concluding contracts on PSO efficiency. We fulfilled this aim, aware of the limitations and other directions for further research.

The relative effectiveness rates from the used DEA models vary from 0.15 in the CRS model and 0.21 in the VRS model to the position on the efficiency frontier (1.0). Significant differences occur in the average relative efficiencies between countries using the centralised model of contracting PSO (Slovakia, Hungary) and those using the decentralised model (Czech Republic and Poland). The first group achieved lower values than the second. No significant deviation in the relative efficiency rate has been observed for PSOs being awarded directly or by public tender. Descriptive statistics show a low average amount for contracting authorities also using (but not only) public tendering. From the point of railway undertaking ownership, the statistical test showed no significance in the differences between the average efficiency rate between incumbent and private railway undertakings. After testing our hypothesis, we cannot reject the statistical insignificance of the tested groups, represented by various models of contracting and awarding public services in passenger rail transport.

Our research has been limited by the availability of data related to PSO provided by contracting authorities and the short period since the successful introduction of public tenders in the V4 countries. Therefore, we could not compare the change in efficiency with time, which might be a crucial factor for comprehensive evaluation. Nevertheless, it is necessary to evaluate the partial effects for further direction and decision-making processes at public authorities ensuring public passenger transport services. From a statistical viewpoint, we were limited in using nonparametric methods because the specific dataset does not follow the condition of normality, whereas these tests are typically less sensitive. DEA models used to evaluate relative efficiency highly depend on the selected inputs and outputs, which can also affect the research results. For further research, it would be appropriate to involve more EU countries with experience in public tendering and evaluate the change in efficiency with time.

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Annex DEA model composition

Contracting authority	Inputs			Outputs	
	Number of passengers (mil. pas) *	Operational performance per km of operated route (tkm/km) **	Transported passengers per 1 inhabitant ***	Compensation per 1 tkm (PPS/tkm) ****	Compensation per 1 passenger (PPS/pas) ****
Jihočeský region	3.95	6,150.85	6.13	5.80	8.82
Jihomoravský region	22.39	11,630.28	18.78	5.57	2.26
Karlovarský region	6.11	5,643.85	20.74	4.31	1.95
Královehradecký region	5.03	7,827.79	9.12	3.56	3.96
Liberecký region	5.16	7,667.15	11.63	4.77	3.90
Ministry of Transport	72.13	3,912.01	6.74	6.47	3.35
Moravskoslezský region	13.90	11,094.36	11.58	6.48	3.43
Olomoucký region	9.87	10,125.52	15.62	6.18	3.79
Pardubický region	4.74	8,893.83	9.07	5.60	5.67
Plzeňský region	7.01	7,577.48	11.88	5.73	4.36
Praha city region	16.71	23,307.35	12.62	9.42	3.20
Stredočeský region	9.24	12,574.76	6.67	6.16	10.80
Ústecký region	11.20	7,657.83	13.64	6.11	4.29
Vysočina region	2.36	6,504.33	4.63	5.52	9.50
Zlín region	4.03	5,758.22	6.92	5.57	5.28
Kujawsko-Pomorski region	9.00	4,904.09	4.34	4.97	3.24
Lódzki region	15.80	5,940.69	6.44	5.29	2.15
Lubelski region	4.10	2,527.47	1.94	7.80	5.25
Lubuski region	3.70	3,505.93	3.66	4.74	4.16
Malopolski region	16.00	6,219.96	4.69	6.33	2.66
Mazoviecki region	104.90	11,264.57	19.34	5.63	1.04
Ministry of Infrastructure	48.90	2,672.25	1.27	3.81	3.91
Opolski region	5.40	4,292.99	5.50	4.41	2.75
Podkarpacki region	4.80	3,118.61	2.26	6.57	4.17
Podlaski region	2.40	2,377.81	2.04	4.68	3.51
Pomorski region	61.00	8,754.13	26.03	3.98	0.69
Swietokrzyski region	3.10	2,839.34	2.51	5.31	3.51
Velkopolski region	31.60	6,612.05	9.03	4.55	1.80
Warminsko-mazurski region	5.00	2,638.52	3.51	5.80	3.48
Zachodniopomorski region	9.80	4,891.12	5.78	5.03	3.00
Slovakia	81.42	8,941.37	14.94	8.68	3.41
Hungary	146.89	11,151.42	15.03	6.39	3.61

* Sources: DATAcube, 2022; Ministry of Transport of the Czech Republic, 2020; Transport statistics of Hungary, 2022; Urząd Transportu Kolejowego, 2020

** Sources: Ministry of Transport of the Slovak Republic, 2022; Summary reports on public service obligation provided by the Czech Republic regional authorities, 2022; Summary reports on public service obligation provided by voivodship authorities of Poland, 2022; Summary reports on public service obligation provided by the Ministry of Infrastructure of Poland, 2022; Summary reports on public service obligation provided by the Ministry of Transport of the Czech Republic, 2022

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