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Research Article

Rail Freight Transport Market Liberalization After Two Decades of Its Beginning

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It has been almost 2 decades since the opening of the rail freight market in the EU came into force. The individual Member States have put different liberalization measures into practice, and the situation on the market still varies from country to country. Efforts to create a single European rail market therefore still seem to be unfulfilled, while, at the same time, the call for a shift of freight transport from road to rail in the context of the European Commission's decarbonization targets is growing stronger. This paper provides a detailed overview of the rail freight market liberalization process and new market entrants in the EU Member States. A trend analysis of the time series was carried out, taking into account the current status of liberalization measures and the development of transport services since 2007. The resulting model uses cluster analysis as the main approach for grouping the countries based on the similarities in the rail freight market, taking into account the performance indicators, the number of licensed railway undertakings in the market and their evolution, and, last but not least, the change in the modal share of rail transport during the period considered.

JEL Classification: R40

Keywords: cluster analysis; freight railway; modal split; rail liberalization; rail licenses

1. Introduction

It is almost 20 years since the European legal framework for opening up the rail market with freight transport services came into force. Today, the situation in the EU Member States is still not the same, and the degree of liberalization of this segment of the rail market varies from case to case. While, in some states, the market is already fully competitive, in another, only statutory administration has been introduced, and there are still barriers to market entry and the development of private or international railway undertakings (RUs). The original idea of a single European railway market is still not realized at the required level, and it is time to make a comprehensive assessment of the current development and to develop a further vision.

Open competition on the market, also known as open access, is a form of competition that can generally be implemented on routes where a profit can be expected. RUs operate their services at their own commercial risk without being compensated by the state or regional authorities. Competition in the market takes place primarily in the area of freight transport, where a mandatory market opening for commercial open access in the Member States took place in 2007. The market is characterized by free economic competition involving both incumbent and nonincumbent RUs, with nondiscriminatory conditions for access to railway infrastructure and no cross-financing of freight transport. It all began in January 2002, when the European Commission proposed a new regulatory framework, known as the second railway package, aimed at revitalizing the railways through the rapid development of an integrated European railway area. The measures in the second railway package are primarily aimed at increasing safety and interoperability and opening up the market for rail freight. The Commission also proposed the establishment of a European Railway Agency (ERA), which would be responsible for providing technical support in the area of safety and interoperability.

The aim of this paper is to evaluate the current state of the rail freight market in the EU Member States from the point of view of its liberalization and, based on this, to propose possible directions for the future regulatory framework. A complex overview of the market players, their market entry, and the duration of their activity in the market, supported by the analysis of the development of transport performance, forms the basis for the proposals on the future evolution needed to change the modal split in favor of rail transport in line with the objectives of sustainability and carbon neutrality.

2. Theoretical Background

A literature review and an overview of the overall liberalization process of the European railways in the freight market from both a legal and a practical perspective form the theoretical basis of this study, together with an overview of previous results of research studies by various authors dealing with the development of the rail freight market.

2.1. Literature Review. Several authors have addressed the issue of liberalization of the rail freight market in their studies. Shortly, after the start of the structural reforms, Schmidt [1] focussed on determining the correlation between prices, performance, and the number of RUs in the market. The author estimated a structural model in which prices and performance depend on the number of companies. The model suggests that company mergers may be desirable for the competitiveness of freight transport, although they would reduce the market power of individual companies. Ludvigsen and Osland [2] provided an overview of the rail reforms in the EU states 30 years after the start of the process. The study looked at the implementation of the first railway package and the attractiveness of rail freight transport in the EU and the economic, social, and environmental benefits of rail liberalization. In the area of the freight transport market, they assessed the process of implementing market liberalization from the point of view of creating legal conditions for commercial open access in this service segment and the current state of competition in the market. At that time, the Czech Republic, Poland, and Romania were among the pioneers in the entry of competition into the rail freight market. In the end, the authors found that there are still barriers to market entry for new companies in some countries.

Cowie [3] compared a particular model of rail reform in the United Kingdom (privatization) with a model of partial deregulation in the United States and its impact on freight transport. The conclusion of the study is the confirmation of the correlation between the entry of competition into the market, the increase in transport performance, and the reduction in transport prices, whereby the development on both continents was clearly different. While the reform had a major impact on the indicators mentioned in the United States, the effect of privatization was rated as very low in the United Kingdom. Dolinayová et al. [4] evaluated the deregulation of the rail freight market in the countries of the Visegrád Four from the perspective of charges for the use of rail infrastructure and from the perspective of the share of freight transport in the overall modal split. The authors assessed the correlation between the individual indicators, while concluding that the liberalization of the market in these countries has not yet had the expected impact. An insight into the relationship between market deregulation and modal split share is also provided by Esposito et al. [5]. To confirm this relationship, they used the Prais–Winsten regression method for a sample of 21 EU countries with data for the period 1993–2013. The results of the analysis show a "relatively strong correlation between the specified factors, but the effect size was relatively small for both samples." This fact could indicate that individual states focus only on market liberalization, but economic growth and growth in the modal share of rail freight also require the introduction of other measures.

The extent of competition in the rail freight market and the market share of new companies entering the market were discussed by Laroche et al. [6]. The authors examined the impact of liberalization 7 years after the full opening of the market to commercial open access, for which they used the "persistence of profit" method. In the end, they assessed the reduction of sunk costs and the increase in the attractiveness of the market as the main benefits of liberalization. Barriers, on the other hand, include the ratio of capital costs to labor costs, which increases the costs for new entities entering the market, and imperfect competition in the market. In their paper, De Francesco and Castro [7] explained the cross-country differences in the implementation of EU rail regulatory reform in the EU-15, taking into account the institutional functions of national independent agencies. Bougette et al. [8] were looking for the best access for individual assets for an effective liberalization of the railway sector. Authors proposed to systemize the "remedies" through asymmetric and enduring ex-ante regulation. Boldiszar and Meszaros [9] conducted a spatial economic study on rail freight transport in the European Economic Area, examining EU transport policies over the last decade. The result in the form of an econometric model has proven that there is a spatial correlation between rail freight performance and GDP in Europe, which has a positive impact on high GDP countries and vice versa. Solina and Abramović [10] in their study analyzed various sources to understand better different correlations between the traffic parameters of the railway freight transport market. This research pointed out the need for seeing a broader picture of state interventions in the context of preventing market marginalization. Barczak [11] looked at the impact of the COVID-19 pandemic on rail freight transport in Europe. The author has carried out a trend analysis and then produced a forecast for the next 2 years using the seasonal index method.

Vida et al. [12] dealt with the very topical issue of modal shift from road to rail. The authors gave an overview of the conditions that need to be met for this modal shift, focusing mainly on the benefits of intermodal transport. The resulting freight transport model provided a solution in the form of an estimate of additional intermodal traffic. A model verification was carried out using the example of the Visegrad 4 countries. Djordjević et al. [13] looked at the efficient use of European rail freight corridors as a means of ensuring the decarbonization of the transport sector in Europe. The authors applied data envelopment analysis (DEA) to evaluate the efficiency of freight corridors based on rail freight performance indicators. The study also considered the potential impact of the digital automatic couplers (DCA) on the resulting efficiency. Bal and Vleugel [14] examined the issue of climate change and its impact on rail freight. The authors looked at factors such as availability and quality of rail freight services. The main question in the paper is "What options governments have to make this mode of transport more resilient to the disruption caused by climate change, with interoperability seen as one of the main advantages of the rial."

Another important issue in connection with the liberalization of the rail market is the question of public subsidies. Yin et al. [15] addressed the issue of subsidizing rail freight transport and carbon trading in a low-carbon transport network. Their mathematical model takes into account transportation costs, carbon trading costs, and transportation time. The authors also conducted a sensitivity analysis for rail freight subsidization and carbon trading price. Khomutov [16] analyzed the current Russian rail freight tariffs, focusing on the effectiveness of the subsidized sector of rail freight transport in the country. The analysis showed that transit subsidies from the differentiated railway tariffs are quite high. The author was mainly concerned with the transportation of coal products, which are also subject to subsidies.

Brumercikova and Sperka [17] addressed the issue of access to station services for rail freight operators using the analytical hierarchy process. Troch et al. [18] focussed on the added value of rail freight transport in Belgium. The authors considered three main indicators of value added—production unit, labor unit, and range for the incumbent rail transport operator. The results also suggest that the liberalization of the rail freight market encourages rail freight operators to improve their efficiency by rethinking their business. Mülke et al. [19] created a model that integrates the demand for rail services, the systemic capacity design of production factors, the operational efficiency, and the financial viability of the planned rail operation of a specific rail freight project. They demonstrated the impact of operational efficiency on the capacity of rolling stock fleet.

In the scientific databases, we can also come across authors who focus on rail markets outside the European Union. Ali Berawi and Miraj [20] examined the example of Indonesian railways and conducted a comparative analysis of this railway reform with two EU members—Germany and France.

2.2. Legal and Practical View on the Freight Market Liberalization. In connection with the planned opening of the rail transport market in the EU, the European Commission has issued a series of directives and regulations, also known as railway packages. To date, four railway packages have come into force. The aim of the first railway package, which was adopted in 2001, was to give RUs nondiscriminatory access to the trans-European rail network. This was achieved through the directives governing the granting of licenses to RUs and the rules for access to railway infrastructure, including the collection of charges for the use of this infrastructure. This was immediately followed by the structural reforms, the so-called vertical and horizontal reform of the RUs. In the vertical reform, an infrastructure manager and the incumbent RU were established as at least two independent accounting units. Similarly, the horizontal reform is characterized by the separation of passenger and freight transport services. If these two entities remain part of a holding or parent company, we can refer to this as vertical or horizontal integration; in the case of institutional separation, we speak of vertical or horizontal separation. Figure 1 shows the current overview of the type of vertical railway reform in the EU Member States.

In most EU countries, a horizontally integrated model has been maintained within a company with accounting separation of activities related to the operation of passenger and freight rail transport. Horizontal separation was only implemented in some countries—Denmark, Estonia, Hungary, the Netherlands, Slovakia, and Sweden, as shown in Figure 2. In most of these countries, this was a preparation for the privatization of freight transport, which, in some cases, has already been implemented or is planned for the future.

The second railway package of 2004 accelerated the liberalization of rail freight transport by fully opening up the rail freight market to competition from January 1, 2007. In addition, the package created the European Railway Agency based in Valenciennes (France), introduced common procedures for investigating accidents, and established safety authorities in each member state [22]. The 2nd railway package consisted of the following legal acts:

- Directive 2004/49/EC of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/CE on the licensing of RUs and Directive 2001/14/CE on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification,
- Directive 2004/50/EC of 29 April 2004 amending Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC of the European Parliament and of the Council on the interoperability of the trans-European conventional rail system,
- Directive 2004/51/EC of 29 April 2004 amending Council Directive 91/440/EEC on the development of the Community's railways,
- Regulation (EC) No 881/2004 of the European Parliament and of the Council of 29 April 2004 establishing a European Railway Agency [22].

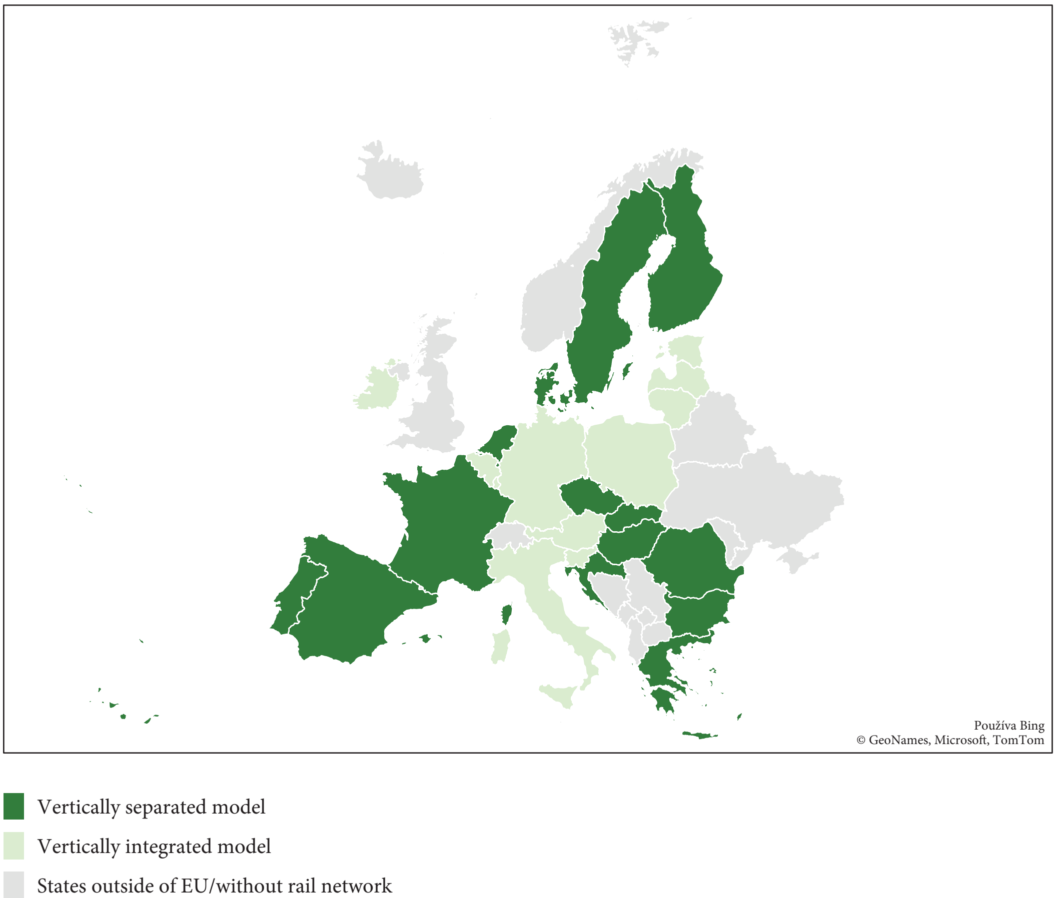

Figure 1: Vertical railway reforms in the EU [21].

The most important piece of legislation with regard to the liberalization process is Directive 2004/51/EC on the development of the Community's railways. On the basis of this directive, "licensed railway undertakings are granted rights of access to the trans-European rail freight network and, from 2008 at the latest, to the entire network for international rail freight services." The Commission assumed that "The extension of these access rights to all types of rail freight services from January 1, 2007, would improve the efficiency of rail transport compared to other modes of transport, in accordance with the principle of freedom to provide services." The main objective was therefore to improve the modal split of rail freight transport at the expense of other modes of transport, especially road. This legislation also regulates access to terminals and ports serving more than one customer, which must be granted to all RUs on a non-discriminatory and transparent basis [23].

The recast of the first railway package, formally known as Directive 2012/34/EU, consolidated and simplified three previous directives into a single legal framework. In addition, the recast Directive clarified existing provisions on funding and maintenance of infrastructure, access to rail-related facilities and the independence of regulatory bodies [22].

The third railway packages introduced in 2007 aimed primarily on the sector of passenger transport, introducing the open access competition for the international passenger transport services and dealing with the rail passengers' rights. The last, fourth railway package from 2016 comprises two pillars—technical pillar which dealt with the interoperability of the railway system within the EU and the railway safety. Based on this package, the European Union agency for Railways (ERA) has been established. The market pillar deals, similarly than the 3rd package, with the passenger transport market, specifically with the award of public service obligation (PSO) contracts [22].

The EU railway packages, particularly the first and second, aimed to introduce open access and improve competition. However, their implementation leaves room for interpretation at the Member State level. The distinction between formal separation and effective operational independence continues to shape market dynamics. In particular, those countries that apply a vertically integrated model of infrastructure manager and RU under a holding company have problems complying with non-discriminatory access to railway infrastructure. Another example are the countries with a dominant position of incumbents supported by the government (e.g., Hungary or the Balkan countries), which makes it difficult for new RUs, both private and foreign incumbents, to enter the market.

Figure 3 gives an overview of the current situation regarding the implementation of open competition in rail freight in the Member States, distinguishing between

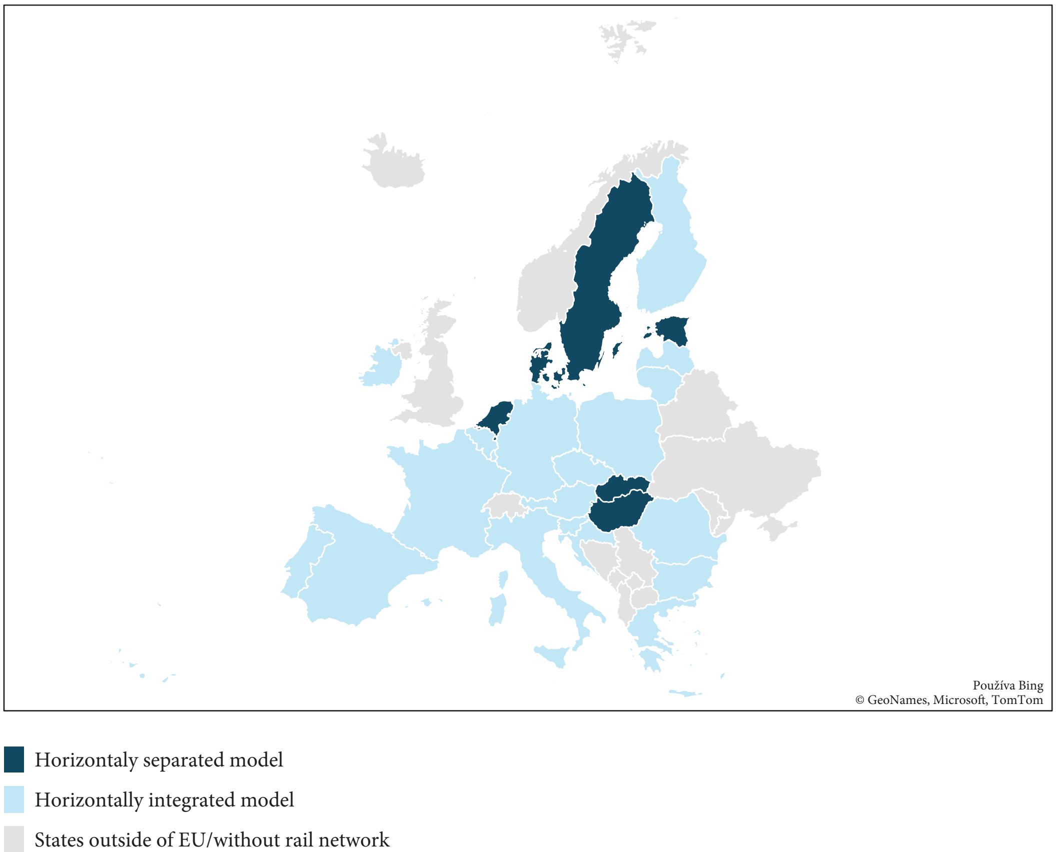

Figure 2: Horizontal railway reforms in the EU [21].

competition "de iure" (legal framework only) and "de facto" (actual entry of new RUs). In recent years, almost all countries have opened up their markets to genuine competition, but the proportion of nonincumbents in the market is still lower in countries with an "obstructive" environment.

Figure 4 provides the market share of incumbent (state-owned RU) and nonincumbents (both foreign incumbent and private RU) on the transport performance expressed in tonne-kilometers in individual Member States. These are the newest available data from year 2022 and include also countries outside of the EU, which are members of Independent Regulatory Group for rail.

As we can see, the market position of incumbents remains strong in all countries, with the exception of countries where the national rail freight operator has been privatized by the private sector or foreign incumbents as part of the horizontal railway reform (Netherlands, Estonia, and Portugal) or as a result of the crisis (Greece). In addition, a higher proportion of nonincumbent RUs are characteristic for post-Iron Curtain countries (Czech Republic, Poland, and Hungary) and some southeast and eastern Europe countries (Romania, Croatia, and Bulgaria) as well as countries with an advanced degree of rail market liberalization such as Germany or Sweden. However, the strong position of the German incumbent DB Cargo (41%) or the Swedish incumbent Green Cargo (50%) on the national markets is still visible [24].

Drawing on the theoretical insights into market liberalization and competition dynamics, the subsequent section outlines the methodology used to examine the effects of policy decisions on the performances of rail freight transport and modal share.

3. Material and Methods

Publicly available databases from Eurostat, national statistics, and national regulatory authorities are used to analyze the current status of the rail freight liberalization process in the individual Member States. Another important data source is the database of active licenses for the operation of rail freight services maintained by the European Railway Agency (ERA), which was set up as part of the 2nd Railway Package. This database contains the number of licenses, the name of the RU, the type of transport services provided, the date of release, and the period of validity. All data were collected for the reference period from 2007, when the legal opening of the rail freight market came into force, to the last publicly available data from 2022 and, in some cases, 2023. All analyses are carried out for the countries of the European Union, with the exception of Member States where no rail network is in operation (e.g., Cyprus and Malta) and Member States where special conditions apply to the rail market (Ireland). In the case of Belgium, there is a lack of reporting of publicly available transport statistics by the

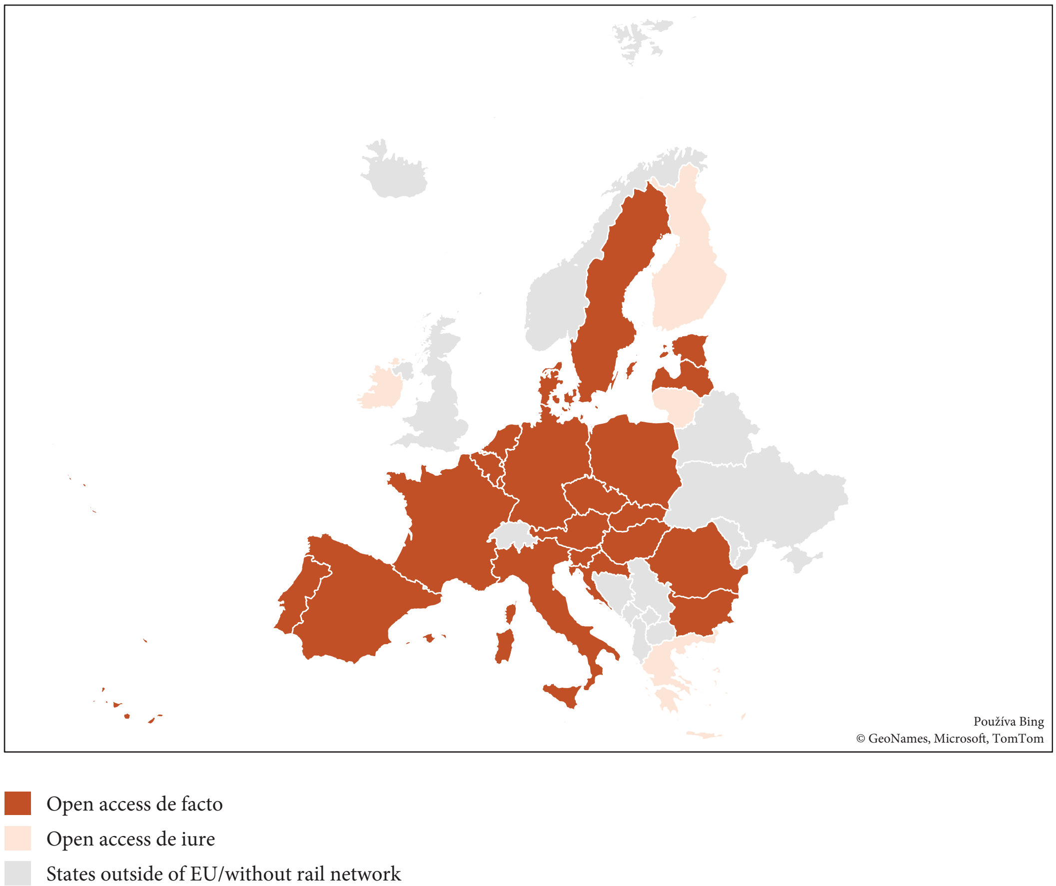

FIGURE 3: Open access competition (freight) in the EU [21].

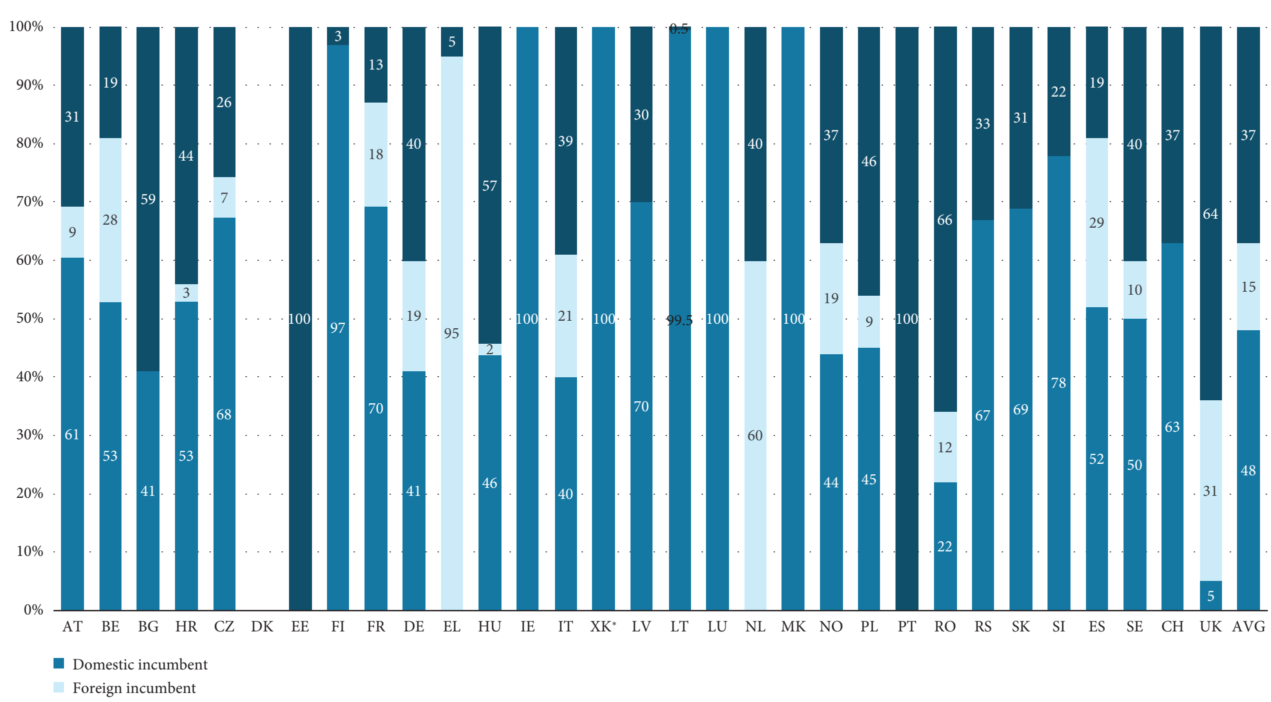

FIGURE 4: Market share of RUs on total transport performance (tonne-km) in percent [24].

competent authorities, which is why this country may be missing in some results and overviews.

A basic analysis of rail freight transport in the EU Member States, including transport performance in tonne-kilometers, is carried out using time series analysis and trend modeling. Another method is cluster analysis to compare the development and current status of rail freight licenses and to group Member States based on similar characteristics. For clustering, we used the k-means method. The block scheme of methodology used is presented on Figure 5.

Time series analysis comprises statistical techniques for analyzing data points over time. The aim is to identify patterns, trends, and seasonal fluctuations in the data. The decomposition of time series is a method used to divide a time series into its components in order to better understand and model it. The most important components of a time series are as follows:

- Trend (T)—the long-term progression or direction in the data,
- Seasonality (S)—regular, repeating patterns or cycles in the data, usually tied to calendar periods,
- Residual (E)—irregular, random fluctuations that cannot be explained by the trend or seasonality.

The decomposition of time series can be approached by two primary models, namely, the additive model (1) and the multiplicative model (2). The choice between these models depends on the type of data. The additive model is suitable when the fluctuations around the trend do not depend on the magnitude of the trend, while the multiplicative model is used when these fluctuations are proportional to the magnitude of the trend [25].

$$Y(t) = T(t) + S(t) + E(t), \quad (1)$$

$$Y(t) = T(t).S(t).E(t). \quad (2)$$

For the decomposition of trend component, several approaches can be used. One of them is the method of simple moving average (SMA). They smooth out short-term fluctuations and highlight longer term trends or cycles. SMA calculates the average of a specified number of consecutive data points in a time series. This moving window of calculation provides a smoothed version of the original time series, making it easier to identify underlying trends.

Other methods used for the seasonal and trend decomposition of time series include the trend elimination using differences or simple linear regression model. More advanced methods, particularly well known in the field of trend forecasting, include ARMA and ARIMA models, simple exponential smoothing, or Holt–Winters exponential smoothing [25].

Clustering is a fundamental technique of unsupervised machine learning and data mining that aims to group a set of objects in such a way that objects in the same group (or cluster) are more similar to each other than those in other groups. The most common clustering algorithms include k-means clustering, hierarchical clustering, or density-based spatial clustering [27].

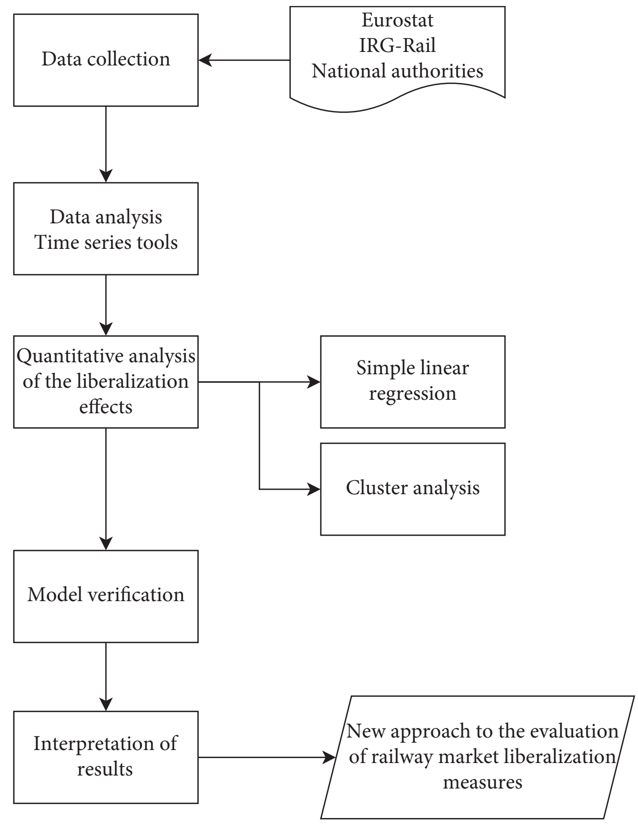

Figure 5: Block scheme of the methodology (author).

K-Means clustering is one of the most popular and simplest clustering algorithms. It divides a dataset into k distinct, nonoverlapping clusters, where k is a predetermined number. The algorithm attempts to minimize the variance within each cluster, which is equivalent to minimizing the squared distances between the data points and the corresponding cluster centroids. K-Means clustering is often used for market or customer segmentation [27].

The k-means algorithm typically follows these steps:

- Initialization—select K initial centroids randomly from the dataset.
- Assignment—assign each data point to the nearest centroid, forming k clusters.
- Update—calculate the new centroids as the mean of the points in each cluster.
- Repeat—repeat the assignment and update steps until the centroids do not change significantly, or a maximum number of iterations are reached [28].

The objective function for k-means clustering can be expressed as

$$J = \sum_{i=1}^{k} \sum_{x \in c_i} \left\| x - \mu_i \right\|^2, \quad (3)$$

where: k is the number of clusters, C_i is the set of points in cluster i, μ_i is the centroid of cluster i, x is a data point in cluster i (Lyu et al., 2022).

The standard k-means algorithm uses Euclidean distance to measure the similarity between data points and centroids. However, other distance measures such as Manhattan or Cosine distance can also be used. Despite its simplicity and ease of implementation, it has some limitations and assumptions that need to be considered. The main limitations include determining the optimal number of clusters, the scalability of the model (ideal for small and medium sized datasets), and the cluster shapes, which are in the form of spherical clusters of similar size. The elbow method is commonly used to determine the optimal number of clusters. This method consists of plotting the within-cluster sum of squares (WCSS) against the number of clusters. The optimal number of clusters is given by the "elbow" point where the improvement in WCSS slows down [29].

Applying the time series analysis and clustering techniques described above to the evaluation of rail freight market liberalization effects, the following findings introduced in the result section of the article were obtained, highlighting the market performance development and entry of new subjects.

4. Results

The first part of the results presents a detailed analysis of the development of the rail freight market since the first measures for the entry of new market participants came into force. The data basis is the time series data of a period of 17 years (2007–2023), reported on a quarterly basis. We consider this time series to be long enough to obtain relevant results in terms of statistical significance and for the evaluation of the liberalization process to date. The transport performance analyzed is expressed in tonne-kilometers, a base unit that multiplies the volume of goods transported by the average transport distance.

4.1. Freight Railway Transport Market Development. The first part of the results section focuses on the quantitative analysis of the development of selected market indicators for rail freight transport, in particular transport performance, as well as the structure of the share of rail transport in total freight transport. Time series methods were used for this analysis, specifically average growth indicators and the decomposition of time series, including the identification and analysis of trend components.

Looking at the development of transport performance within the Member States between the implementation of the law in 2007 and the end of 2023, expressed by the average annual growth in percent (Figure 6), most countries show an increase in this key performance indicator, but not a significant value, ranging between 0.1% and 2.6% of the average annual growth over the entire period. The only exception is Luxembourg with an average annual growth in rail freight of around 25, which is due to the sharp increase between quarters in 2011. In contrast, Estonia recorded the strongest average annual decline of almost −11%, followed by two other Baltic countries (Latvia and Lithuania), which is probably linked to significant changes in the flow of goods between Europe and Russia.

A more detailed development of the performance of rail freight transport within individual countries can be seen from the time series decomposition. The quarterly data for the period 2007–2023 were analyzed and decomposed to 4 basic components, of which the trend component is the most important for us. The trend, adjusted from seasonal and cyclical fluctuations, can give us a more reliable overview of the development of transport performance and is a suitable tool for comparing the markets in the Member States with each other. Time series decomposition itself was carried out in the R language environment using the "ts" library. Figure 7 shows the individual trend components of the transport performance of the original time series, expressed in million tonne-kilometers for each Member State.

Analyzing the general factors influencing performance across Member States, a noticeable decline is observed after 2020, primarily due to the COVID-19 pandemic and, subsequently, the war in Ukraine. These events significantly disrupted the flow of goods between Europe and Asia and adversely impacted domestic industries within Europe. The most substantial growth in performance occurred shortly after 2015, likely linked to the recovery from the global economic recession that had negatively affected performance since the beginning of the evaluated period. A comparable downturn was evident in most countries both during the early years (2007–2015) and again after 2020.

Based on the time series analysis, we have identified groups of countries with regard to the trend development of the rail freight market. The first and smallest group is characterized by a continuous decline in transport performance and includes only the Baltic state of Estonia. For each country, it can be seen that there is a downward trend after 2020 caused by the current crises, in particular the COVID-19 pandemic and the war in Ukraine. The second group is characterized by a general increasing trend. Of course, there are fluctuations and decreases during the observed period, but compared to the 2007 values, the traffic performance at the end of the period reaches the same or even higher values. This group includes Austria, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Italy, the Netherlands, Poland, Portugal, Slovenia, and partly also Sweden, where frequent fluctuations can be observed, but the trend generally increased after 2015 and peaked at the values from the beginning of the observation period (excluding the crises after 2021). Conversely, the third group shows a general decreasing trend with fluctuations, with transport performance at the end of the period no longer reaching the values of 2007. This type of trend is characteristic of Denmark, Finland, France, Greece, Latvia, Lithuania, Luxembourg, Romania, Slovakia, and Spain.

If we want to evaluate the impact of the liberalized market on the basis of the development of performance in the rail freight market, the only positive effect is not entirely obvious. The size of the individual groups formed on the basis of trend development (general increasing and decreasing) is about 50/50. The level and development of the liberalization process of the rail freight market in the individual Member States does not even reflect the allocation to our groups. There are some countries with a less advanced

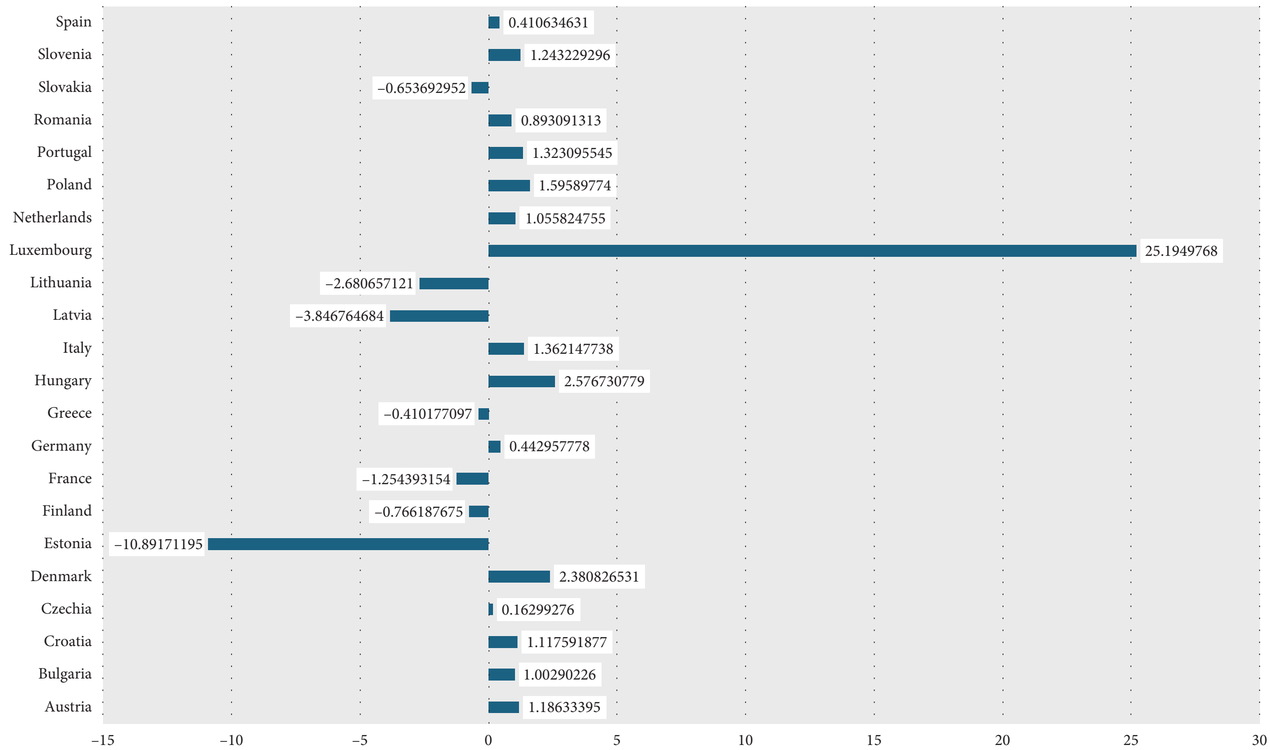

Figure 6: Average annual growth of transport performance (mil. tonne-km) in the EU (author by Database-Eurostat [30]).

level of the freight market liberalization which can be characterized by a generally increasing trend of performance, e.g., Croatia or Portugal. In the group described by a generally decreasing trend, the majority of countries can be characterized as those with more restricted market access, but there are also some exceptions, such as Slovakia and Romania with a significant share of non-incumbent RUs in the market.

In addition to the increase in performance indicators, there was another expectation of the rail reform and the opening up of the rail freight market. The main objective of the overall EU transport policy is to shift freight transport from road to rail; in recent years, it is also supported by the Green Deal policy to decarbonize the EU by 2050. In this part, we will look at the development of the share of each mode of transport, especially road and rail freight, in each Member State. Analogous to the previous case, we have performed a time series decomposition and determined the trend of the modal share of rail transport compared to road transport. The results are shown in Figure 8.

The general trend shows a decrease in the modal share of rail transport in most countries compared to the reference year, with a few exceptions in the case of Croatia and Slovenia. The trend figures differ mainly in the direction of development during the observed period. A decline after 2020 is recognizable due to the current crises and the situation on the freight transport market that occurred then. Table 1 provides a better understanding of the changes in the modal share in the individual countries and a comparison of the values at the end of the period with the reference year. The clearest positive change when comparing the years 2022 and 2007 can be seen in the example of Portugal, where the share of rail transport in the freight transport market has increased by more than 35%, followed by Croatia with an increase in the rail share of around 12.

On the other hand, there was a decrease of more than 60% in Luxembourg and Estonia, followed by other Baltic countries, Greece as an example of a state in crisis, and Poland and the Czech Republic with about 30% negative change in the modal share of rail. In general, this has been in favor of road transport, although one of the main measures the European Commission is aiming for a shift from road to rail through the liberalization of the rail freight market. Although transport performance increased in many cases, this was more in response to the ever-increasing demand in the transport market and, at the same time, the performance of road transport grew even faster.

In order to compare the development of the liberalized rail freight market in the individual Member States, we have divided them into groups, taking into account the development of transport performance, changes in the modal share of rail, and the extent of liberalization measures applied to the market during the observed period, named as the "market liberalization level." This indicator reflects the level of structural reforms applied in the country, combined with the actual competitive environment on the market (Table 2).

As it can be seen from the table, the situation in the individual Member States is very different. The largest group consists of those states in which a minority of new subjects have entered the market since the beginning of the rail reform. This group is clearly characterized by a decreasing trend in rail freight transport services and a simultaneous significant

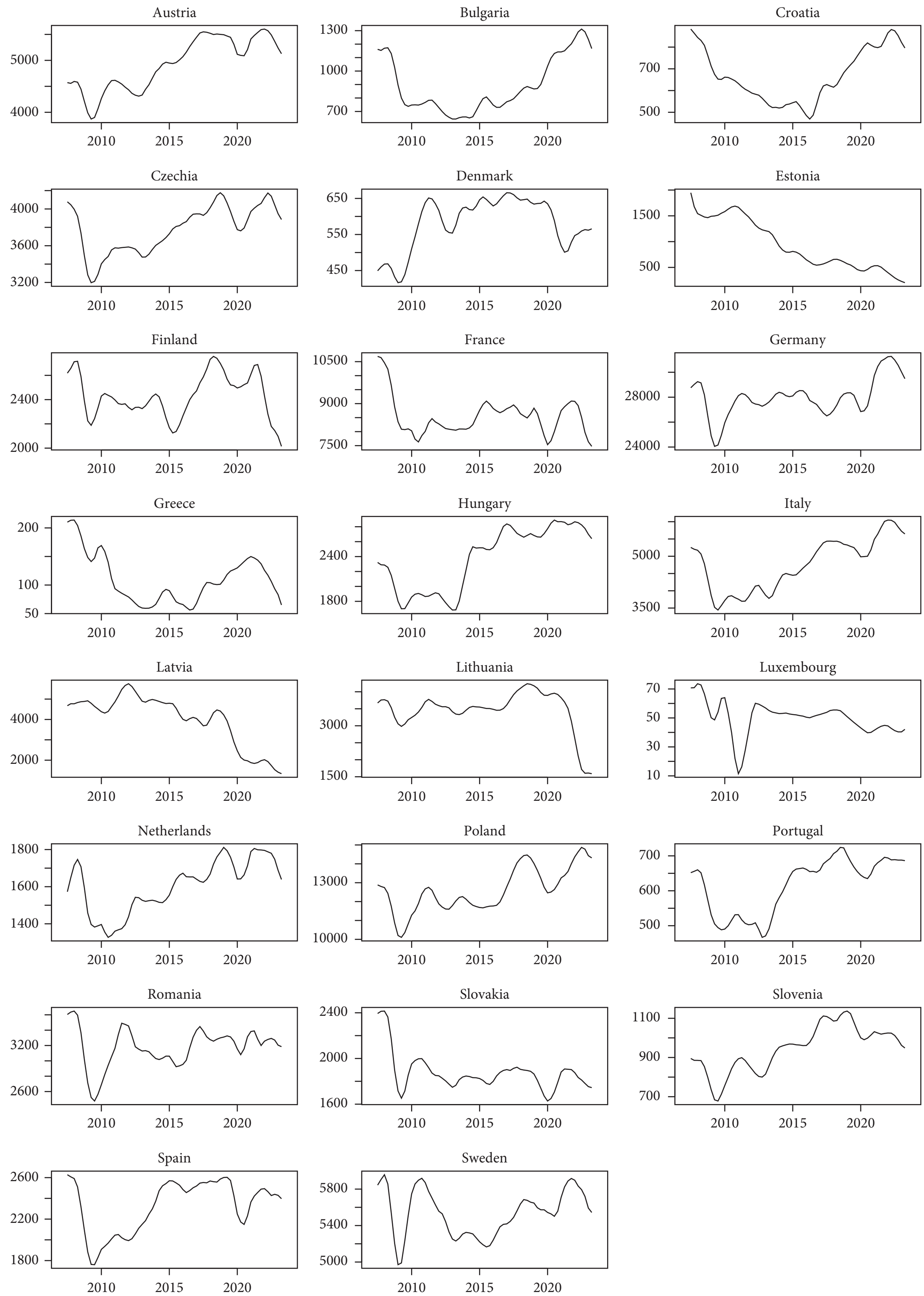

Figure 7: Trend of transport performance (mil. tonne-km) during reference time period (author by Database-Eurostat [30]).

decline in the modal share of rail transport during the reporting period. In other cases, we cannot determine as clearly whether the degree of market liberalization has had an impact on rail transport performance. In some Member States with a fully liberalized market, both indicators have declined simultaneously (Slovakia). The only country with a general

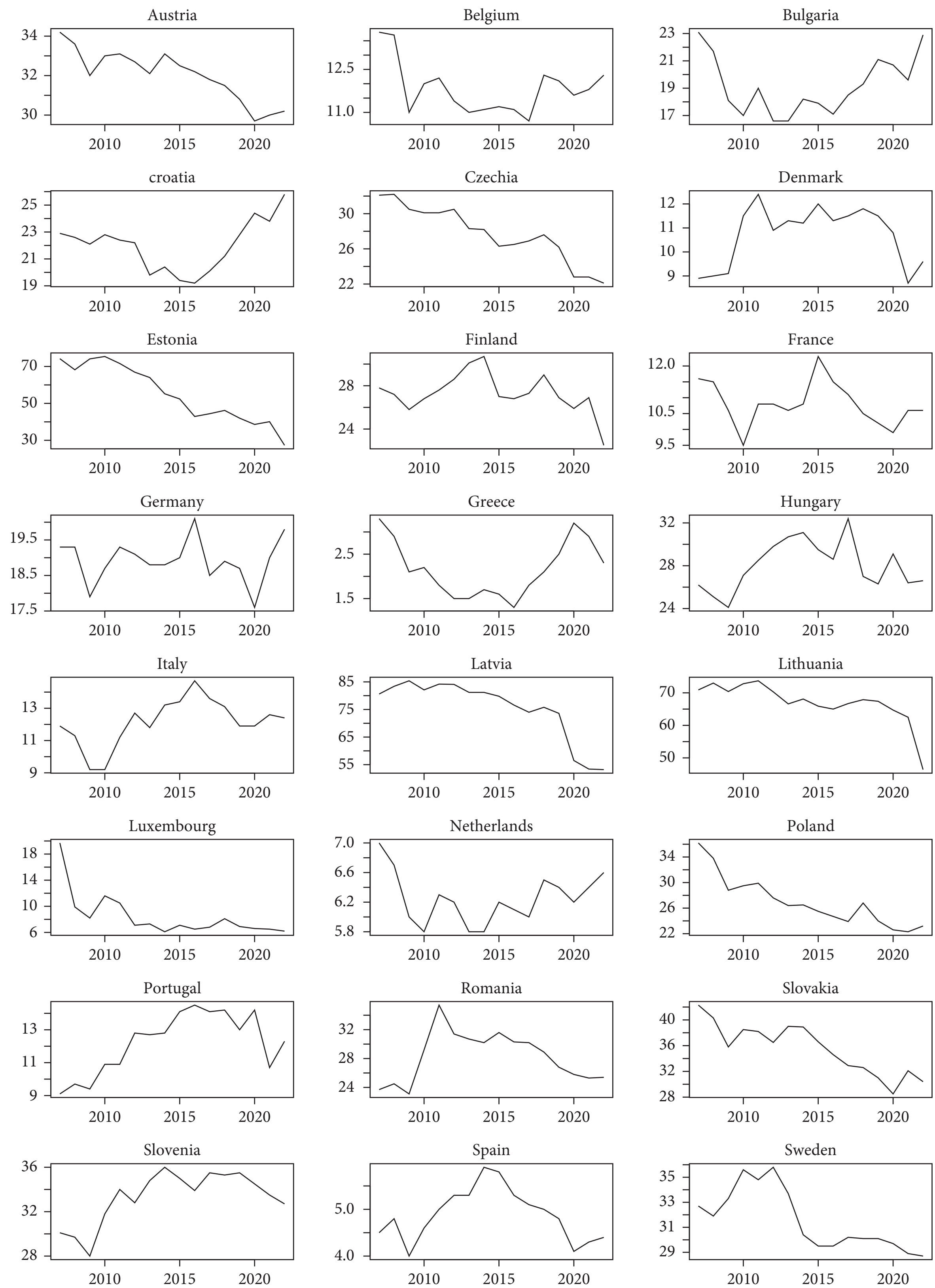

Figure 8: Trend of modal share of freight rail transport (%) during reference time period (author by Database-Eurostat [30]).

increasing trend in transport performance and a significant increase in the share of rail transport is Portugal, where the incumbent still has a dominant and almost monopolistic position in the market. For a deeper understanding of this development, advanced methods must be used to express the dependence on variables based on statistics.

Table 1: Change in modal share of freight rail transport 2022/2007.

Country	Change in MS (%)	Country	Change in MS (%)
Portugal	35.16	Belgium	−10.87
Croatia	12.66	Austria	−11.70
Slovenia	8.64	Sweden	−12.23
Denmark	7.87	Finland	−19.06
Romania	7.17	Slovakia	−28.13
Italy	4.20	Greece	−30.30
Germany	2.59	Czechia	−31.15
Hungary	1.53	Latvia	−34.00
Bulgaria	−0.87	Lithuania	−34.56
Spain	−2.22	Poland	−35.91
The Netherlands	−5.71	Estonia	−63.21
France	−8.62	Luxembourg	−68.53

Note: Source: author by Database-Eurostat [30].

4.2. Market Entry of Railway Undertakings. The European Railway Agency (ERA) manages the European railway agency database of interoperability and safety (ERADIS) database with current and historical valid licenses issued by the national regulatory authorities of the individual Member States. This database contains all the important parameters of the license, such as the RU, the release date and, if applicable, the period of validity, the type of transport services provided (passenger transport, freight transport, combination of both, and traction only), and the name of the issuing organization. In general, the possession of a license to operate rail freight services does not always imply the actual provision of these services. In some cases, operators of passenger services apply for a license for both passenger and freight services at the same time. Another special case are infrastructure managers and construction companies that require the license to operate freight services in connection with their activities, e.g., when modernizing or maintaining railway infrastructure.

Figure 9 provides an overview of the active RUs with the license for the provision of rail freight services issued in the individual EU countries by the end of 2023. The frontrunner in terms of the number of licenses issued is Germany with a total of 458 licenses with 250 active RU, followed by the Central European countries of Poland, the Czech Republic, and Slovakia. The least liberalized rail freight markets in terms of absolute number of licenses and active RU are the Northern European countries, with the exception of Sweden as one of the pioneers in the field of railway reforms, the Baltic post-Soviet countries affected by the incompatibility of the rail network (wide gauge) with the rest of the EU, and last but not least the Benelux countries Belgium and Luxembourg, where paradoxically the legal framework for railway reforms was created. The strong position of national incumbents in the Western part of Europe, reinforced by the vertically and horizontally integrated structure of RUs, leads to a disproportion in the number of RUs active on the market (or entering the market) compared to the post-Iron Curtain states, where the liberalization process has triggered a big boom of nonincumbent RUs entering the market to compete with the poorly performing and underfunded incumbents, which have the reputation of an unreliable logistics partner.

The actual number of RUs providing freight services in each country does not necessarily replicate this development, but it is a good indicator of market size when compared with each other. Some RUs hold a license for a specific type of service, or they operate freight transport only to the extent necessary to maintain it. While Germany leads in the number of active RUs, this does not necessarily equate to a fragmented or balanced market. Anecdotal and industry data suggest that a small number of large RUs dominate the majority of the transport volume, while the rest are either niche operators or dormant license holders. Future research could benefit from examining concentration ratios, such as the Herfindahl–Hirschman Index (HHI), to assess market dominance and competition more accurately. However, the required performance data at the company level are not currently available in a consolidated form.

The trend in the number of rail freight licenses issued has been positive in most Member States during the period under review. Figure 10 shows a difference between the number of licenses for freight transport companies at the end of 2023 compared to 2007, when the legal opening of the market was introduced. In line with the total number of licenses, the largest increase was recorded in Germany with 292 new licenses issued. Looking at the total number from the previous figure, it can be seen that the rail freight market was already excessively open before the EU legal act on the second railway package came into force. Germany is followed by the Central European countries, in particular the Czech Republic, Slovakia, and Poland, where a large number of new licenses had already been issued during this period. The smallest increase in new licenses was recorded in the Baltic countries, the Benelux countries, and the Northern European countries, with the exception of the liberalized Swedish market. The annual increase in new licenses for passenger and freight transport has not changed that much, and we can assume that the decrease is mainly due to the loss of licenses for freight transport due to nonuse.

4.3. Clustering in the Conditions of Freight Rail Market. The absolute number of new licenses issued or the total number of active RUs at the end of the period says nothing about the degree of market liberalization itself. It is necessary to analyze these data in conjunction with other indicators, in particular operational and transport performance and finally the market share of incumbent and private RUs. From the methods of the regular statistical analysis, e.g., the regression model, which expresses a degree of dependency between the compared variables, can be used. Another approach is the cluster analysis to group the Member States into clusters based on the similarity of the compared indicators.

For the regression analysis, we first choose a simple linear regression in which the total performance indicator, expressed in terms of 1 km of the rail network, is a dependent variable y and the total number of licenses for the provision of rail freight transport is an independent variable x. For the simple regression model, data were used that represent the

Table 2: Groups of Member States based on performance time series analysis.

Group	Performance trend	Modal share change	Market liberalization level
Finland, Greece, Latvia, Lithuania, Luxembourg, Estonia	General decreasing	Significant decrease	Without/minority of non-incumbents
Slovakia	General decreasing	Significant decrease	Fully liberalized market
France, Spain	General decreasing	Slight decrease	Partially liberalized market
Romania	General decreasing	Slight increase	Fully liberalized market
Denmark	General decreasing	Slight increase	Without/minority of non-incumbents
Bulgaria, The Netherlands, Belgium	General increasing	Slight decrease	Partially liberalized market
Austria, Czechia, Poland, Sweden	General increasing	Significant decrease	Fully liberalized market
Germany, Hungary, Italy	General increasing	Slight increase	Fully liberalized market
Croatia, Slovenia	General increasing	Slight increase	Partially liberalized market
Portugal	General increasing	Significant increase	Without/minority of non-incumbents

Note: Source: author calculations.

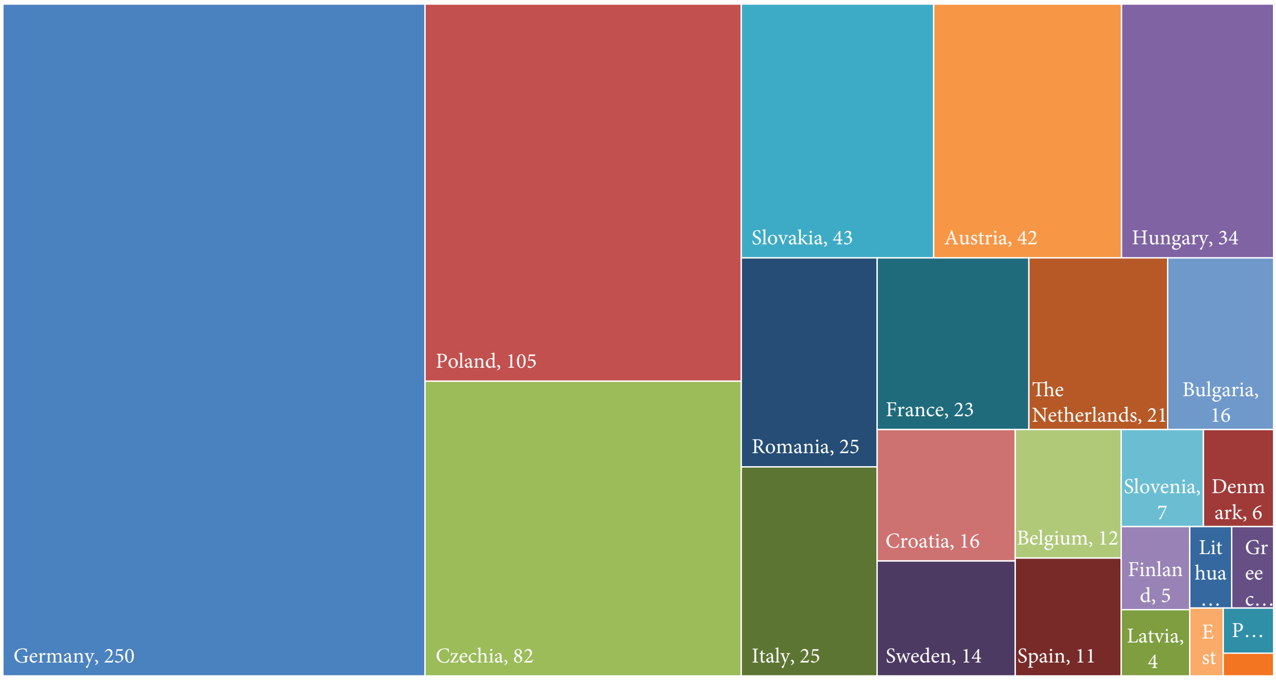

FIGURE 9: Number of active RUs (freight) in the EU Member States in 2023 (author by ERADIS [31]).

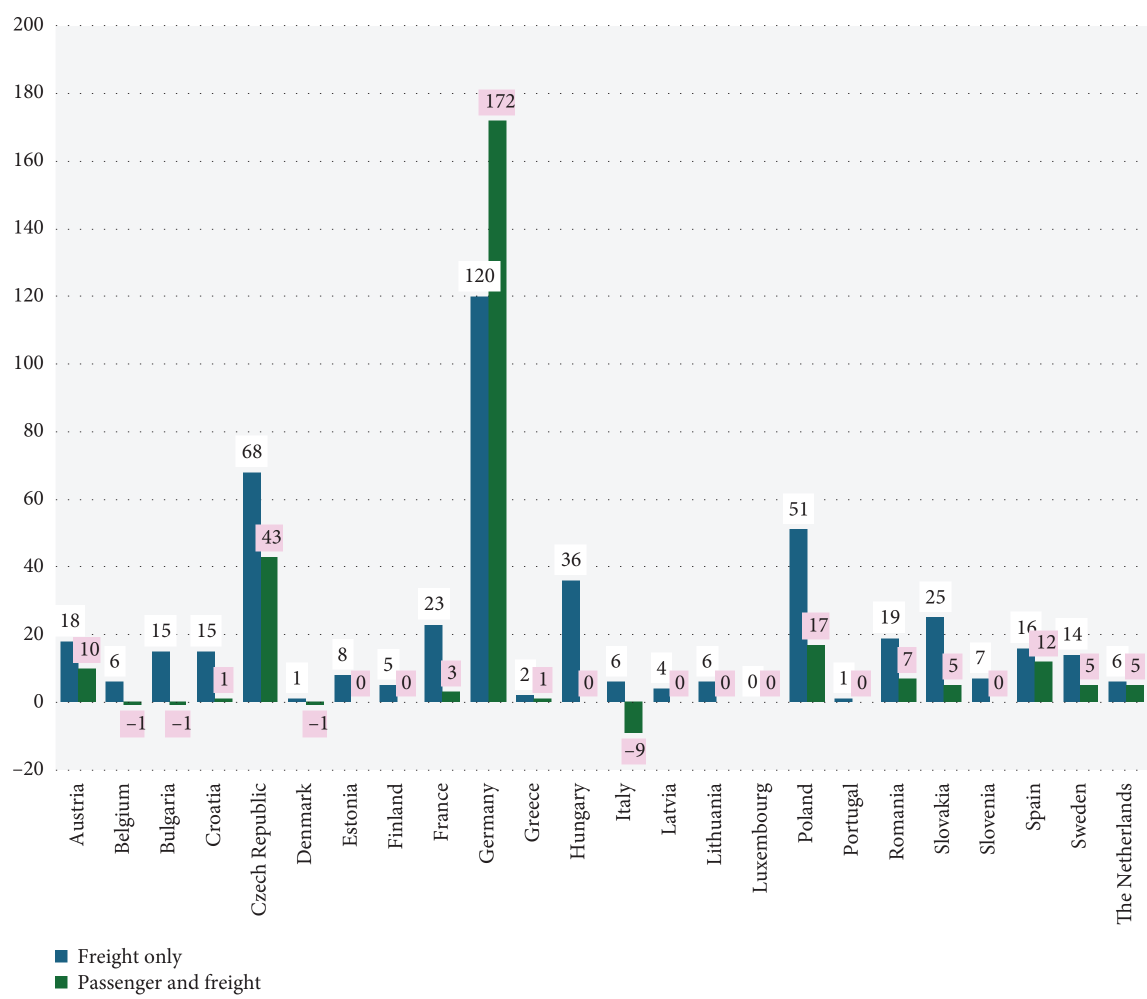

FIGURE 10: Difference in the number of licenses (freight) between 2023 and 2007 (author by ERADIS [31]).

current situation on the liberalized market at the end of 2023. The independent variable is included in the model as the absolute number of active licenses, while the dependent variable is expressed in thousand tonne-kilometers per 1 km of the total route length in operation. This regression model was run in the R language environment using the function "lm." The result of the simple linear model with the statistical summary and the tests for significance is shown in Figure 11.

The model results show that there is no linear dependency between the compared indicators. The p-value of the regression coefficient, i.e., the significance level of the entire regression model, is far outside the permissible values, as can also be seen from the scatter plot (Figure 12). Considering only these two indicators in a basic linear model is an inadequate approach to express the actual dependence or independence between the market entry of RUs and the market size of freight transport in the individual countries.

From this point of view, it is better to use methods other than general statistics to evaluate the development of market entry. We have opted for a cluster analysis using the k-mean clustering method. Based on clustering, we define groups of Member States based on their similarities, taking into account the following market indicators, which are the variables that enter our model:

- Number of active RUs,
- Transport performance expressed on the total network length,
- Market share of nonincumbent RUs on the transport performance,
- Modal share of rail transport expressed by the percentual change during reference time period.

From the resulting model, country groups are determined based on the similarities in the relationships between the influencing factors, which can lead to a smaller number of groups with more precise characteristics than when using the previous approach of time series analysis and trend development. The model calculation and compilation were carried out in the R language environment using the special cluster library.

The first step in performing k-means clustering is to determine the optimal number of clusters. To calculate this number, we used the "Within Sum of Square" method, also known as the WSS or Elbow method. The position of a bend (knee) in the plot is generally considered to be an indicator of the appropriate number of clusters. As can be seen in Figure 13, the elbow or knee belongs to the optimal number of 4 clusters for which the k-means clustering is calculated.

The latest available data from 2023 were used for the first cluster model. Following R code is used for the model construction:

df < - scale(df) #scale each variable to have a mean of 0 and sd of 1

fviz_nbclust(df, kmeans, method = "wss") *#use wss method for optimal number of clusters*

set.seed(1) *#make this reproducible*

```
Residuals:
    Min      1Q  Median      3Q     Max
-1045.1  -484.7  -257.9   231.3  2908.6

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 1118.606    203.167   5.506 1.83e-05 ***
license        1.495      1.935   0.773    0.448
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 865.1 on 21 degrees of freedom
Multiple R-squared:  0.02764,	Adjusted R-squared:  -0.01867
F-statistic: 0.5969 on 1 and 21 DF,  p-value: 0.4484
```

Figure 11: Simple linear regression model for dependency between market entrants versus transport performance (author calculations).

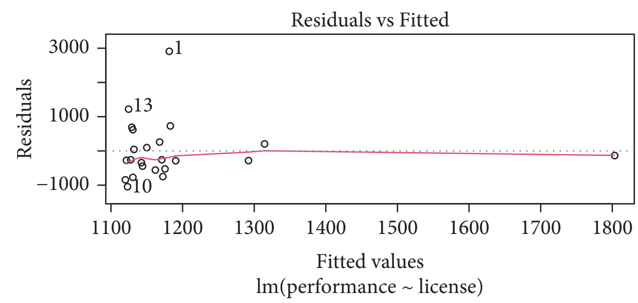

Figure 12: Simple linear regression model—graphical representation (author calculations).

km < - kmeans(df, centers = 4, nstart = 25) *#perform k-means clustering with k = 4 clusters*

fviz_cluster(km, data = df) *#plot results of final k-means model*

After performing k-means clustering in the R language environment with scaled variables, 4 country clusters are shown in Figure 14. A closer look at the differences between the individual clusters is provided in Table 3, which shows the mean values of the individual variables within the clusters. The scaled mean value greater than 0 (average of all evaluated units) stands for an above-average value within the cluster, and analogously, a value less than 0 stands for a below-average value within the cluster.

Cluster 1 is the smallest, represented only by Germany, with the highest mean value for the number of active RUs, above-average volume of transport performance, slightly higher share of new market entrants, and slightly below-average modal share of railway. The largest cluster 2 comprises 9 countries characterized by a highest number of new market entrants, most of which are nonincumbents. In this case, the modal share of rail transport has increased, while the transport performance is slightly lower than in another clusters. The cluster 3 comprises 8 countries, which are characterized by the lowest mean values of all the evaluated inputs. We can assume that in these countries, the degree of market liberalization is not sufficient from the point of view of the actual impact of these measures on the performance indicator, the share of nonincumbent RUs in total performance, and the share of rail freight transport.

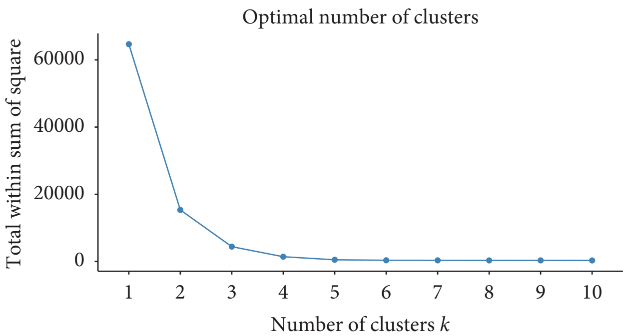

FIGURE 13: Optimal number of clusters using WSS method (author calculations).

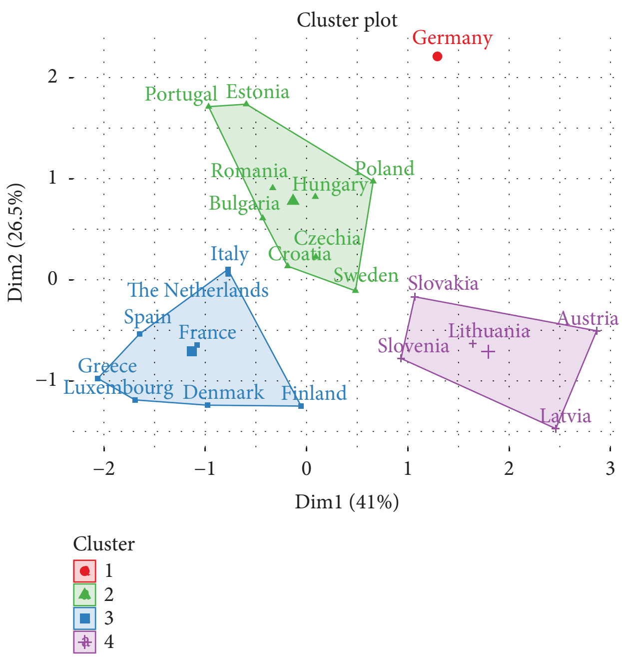

FIGURE 14: Final cluster model for year 2023 (author calculations).

On the other hand, cluster 4, represented by 5 countries that were previously at different levels of market liberalization, can be characterized by highest volume of transport performance and modal share of rail transport within the clusters and, at the same time, by a lower number of new market entrants, especially private ones.

Based on the results presented above, the following discussion will explore their implications in the context of existing research and theoretical frameworks.

5. Discussion

In this paper, two independent approaches were used for grouping EU Member States based on similarities in rail freight market liberalization—time series trend analysis and cluster analysis. Each of the two methods has its own limitations, but from the point of view of complexity and consideration of multiple influencing factors, the cluster method provides more accurate results. The main advantage is the resulting number of groups, where we have only 4 clusters instead of 10 inhomogeneous groups with less significance.

When comparing the results, insufficiently open markets with a decreasing trend in transport performance and modal share of rail are generally part of cluster 3. In contrast to the trend decomposition method, we also find Italy in cluster 3, which was originally in the group with Hungary and Germany. As expected, countries that were previously alone in their own group were assigned to one of the clusters: Slovakia in cluster 4, and Portugal and Romania in cluster 2. The case of Romania versus Portugal is particularly interesting, with a different market situation that plays a significant role but has brought about a major positive change in the modal share of rail in Portugal. Germany is a special case, where a significantly higher number of market participants compared to other countries (even with a similar size) led to it becoming a separate cluster. However, other characteristics are similar to cluster 4, while Germany was ahead of some countries from this group in the previous trend analysis. It is also important to note that the Baltic States (Estonia, Latvia, and Lithuania) may represent a special case in the context of declining freight volumes. Historically, a substantial proportion of their rail freight—estimated at up to 90%—was cross-border trade with Russia. Due to recent geopolitical developments, including sanctions and security restrictions, these flows have largely ceased. Therefore, the observed decline in transport performance and modal share in these countries may be less reflective of internal market liberalization efforts and more a result of external shocks. These facts convince us that it is necessary to consider broader contexts and that both methods make some contribution to the overall results.

The main limitation of this study is the limited availability of data, as some Member States had to be excluded from individual methods and models. For a more accurate decomposition of trend in modal share of rail freight transport, it would be more appropriate if the data were available on a quarterly basis, as in the case of transport performance. In addition to the k-mean method, several other methods of data clustering are also available, but these are characterized by specific data requirements that cannot be met to a sufficient degree. Another important factor that affects the results is the determination of the optimal number of clusters, whereby different methods can also be used here. The close proximity of the results, e.g., the case of the Czech Republic and Croatia, which lie in the range of two different clusters, can also influence the final interpretation of the model. In addition to the above limitations related to the methods used, there are also some limiting factors in the market itself. In practice, transport performance is influenced not only by liberalization and other market policies of Member States but also by technological factors, among which we highlight the capacity of the railway infrastructure. The tracks are occupied by many more passenger services, which have a higher priority in the operational hierarchy and have a negative impact on the flexibility and reliability of rail freight operators.

Based on the results, future development in the rail freight market should focus more on motivating customers to shift their services from road to rail and not only on opening the market to nonincumbent RUs. Reducing the

Table 3: Mean values (scaled) within individual clusters.

Cluster	Active RUs	Transp. performance	Share of nonincumbent	Modal share of railway
1	4.00	0.56	0.16	−0.14
2	0.03	−0.32	0.87	0.16
3	−0.39	−0.57	−0.74	−0.97
4	−0.24	1.39	−0.42	1.30

Note: Source: author calculations.

incumbent's share of transport performance would not always lead to an increase in these services but, as we can see in many countries, would only lead to a sharing of the initial performance between the incumbent and new, mainly private, entrants. There is a clear need to review the reform of the EU rail freight market after 2 decades since the first measures came into force and to focus primarily on measures that support the increase of modal share of rail transport on the transport market and improve the flexibility and reliability of rail transport services. Instead of splitting the current services among several RUs (both incumbent and nonincumbent), it is necessary to exert pressure to attract new customers who currently use the services of road transport carriers, while ensuring nondiscriminatory conditions for open competition in the market, as barriers against new entrants may limit the attractiveness of rail even more. Based on our findings, several policies are proposed to be implemented, from which we highlight the following:

- Re-interpreting the objectives of market liberalization—as it turned out, opening the market to new entrants alone may not bring the desired expectations. In many cases, the only change has been a shift in market share rather than an increase in rail performance. It is necessary to set targets to increase the share of rail transport, regardless of which market player provides it, while maintaining the necessary level of non-discriminatory access to infrastructure.
- Policies related to rail infrastructure capacity—in addition to massive investments to increase the capacity of tracks and stations, the prioritization of freight trains on the main network with mixed operations needs to be reconsidered.
- Financial support for industrial tracks (private tracks used exclusively to serve a particular industrial site)—this measure can help to increase the modal share of rail by shifting the transport of smaller consignments, thus ensuring door-to-door solutions. In the case of single wagon shipment or groups of wagons, this represents the major barrier for companies to use rail transport.
- Distribution of external costs between individual transport modes—this measure can improve the pricing of RUs by giving priority to rail freight as a more environmentally friendly and less energy-intensive mode. Higher cost burden of rail transport is currently one of the main obstacles to increasing the competitiveness in the market.

6. Conclusions

The objectives that the European Commission has set itself in the area of open competition in the rail freight market should have led to a higher share of rail transport compared to road transport, an increase in the number of market participants and the volume of goods transported. Today, it is obvious that these objectives have not been achieved on a global level and that the situation on the freight market varies from one Member State to another. The aim of this paper was to provide an overview of the current situation and the development of the liberalization of the rail freight market in the EU Member States so far and then to evaluate the actual impact of these measures, taking into account various factors such as transport performance, the share of nonincumbents on the market, and modal share of rail transport.

Based on the results obtained by using two different approaches—trend in time series and cluster analysis with the k-means clustering method—we have come to the conclusion that the process of rail freight market liberalization has not brought the expected benefits on a global level and that there are several groups of Member States with similar market situations that differ significantly from each other. The increase in the number of new RUs entering the market itself has not led to a comparable development of other variables such as transport performance or modal share of rail transport. Similarly, there are countries with a significant positive change in transport performance or modal share that have not opened the market to nonincumbents to a sufficient and necessary extent. There is no single approach to say in which of the resulting groups of countries, the reform of the rail freight market in its original form from 2007 onwards has been more successful (or less successful). What we can definitely confirm is that neither in one group nor in the other did the expected effects of rail reform fail to materialize. However, the proposed clusters can serve as a basis for defining follow-up measures at the level of the European Commission, while these measures and legal acts could be defined on the basis of the similarities in the development of the rail freight market in a more individualized approach and taking into account the needs and requirements of the individual groups of states.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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