Article

Convergence of Energy Intensity of the Export of Goods by Rail Transport: Linkages with the Spatial Integration and Economic Condition of Countries

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Abstract: This article concerns the identification of connections between the energy intensity of rail transport and spatial integration (convergence processes in the EU and spatial proximity) and the economic situation of countries that are in international export–import trade relations. Three research questions are formulated in the article: (1) Does the improvement of the economic situation of the importing country reduce the energy intensity of the Polish export of goods by rail transport to the partner country? (2) Does EU integration contribute to reducing the energy intensity of the export of goods by rail transport? (3) Is there a positive spatial effect (convergence) of reducing the energy intensity of the export of goods by rail transport? This study concerned 14 geographical destinations (export destinations from Poland) during the years 2010–2020. A comprehensive study of convergence was used by building a spatial (club) and type β convergence model and using an unconventional method (panel stationarity analysis). It has been verified that there is a convergence in the energy intensity of goods exportation by rail transport in EU countries. The rate of spatial (club) convergence is 8.66% per year, while the period after which this convergence will be halfway between the initial state and the long-term equilibrium point is 8 years.

Keywords: convergency model; Data Science; energy intensity; export of goods; rail transport; spatial integration

1. Introduction

The development of rail transport has stimulated the level of trade since ancient times and has served as a stand-in for economic and civilizational advancement, as it formed the basis for the first forms of competitiveness of transport modes [1–4]. At first, it boosted the economies of the areas by creating backward links, understood as the requirement for building supplies and labor, and forward links, understood as the minimization of transport costs [1,5]. The development of the earliest forms of mobility and the shift in the interaction between space and humans brought about by steam, then electric, then diesel trains also affected the integration of areas through the building of networks of rail lines. Despite the proliferation of motorization and road transport in the 20th century, rail transport is still vital to globalization, network links, and trade [5–7].

The major importance of rail transport in the new "dual circulation" plan is simultaneously underlined, in addition to noting its considerable contribution to increasing the level of international trade between nations located along rail lines and those at the intersection of land links [8]. In other words, by maintaining an open economy, the country may reduce its reliance on foreign markets by focusing on raising domestic demand (or internal demand of integrated countries, e.g., the European Union), and concentration. The integration

and liberalization of transport (also rail transport) were additional manifestations of this globalization [9,10].

The integration of the rail policies of European Union countries was intended, on the one hand, to face the difficulties of sustainable growth and ensure country synergy through reciprocal access to infrastructure, and to encourage the principles of fair competition [9,11,12]. On the other hand, it encouraged the development of rail transport, including intermodal rail freight services. It also outlined transport cooperation with countries, including in the European Neighborhood Policy [11]. The dynamic progress in rail transport in modern economies stems mainly from the expansion of the TEN-T network, the implementation of digital technologies, the implementation of the European Rail Traffic Management System (ERTMS) as a means of interoperability, or the possibility of implementing many EU railway programs for the development of rail transport [13,14]. However, the relatively small participation of this mode in the servicing of all international trade in the EU indicates that rail transport does not yet fully exploit its potential in long-distance transport (more than 300 km) [15]. This tendency can be a challenge for sustainable development, especially as it is one of the least energy-intensive modes of transport [16–18]. In the context of energy dependence, a limited supply of energy carriers, and tense international relations, there is a strong argument for promoting rail transport in meeting the needs of society and the economy to sustain development.

Three research questions were used to frame the problem for the study:

1. Does the improvement of the economic situation of the importing country reduce the energy intensity of Polish export of goods by rail transport to the partner country?
2. Does EU integration contribute to reducing the energy intensity of the export of goods by rail transport?
3. Is there a positive spatial effect (convergence) of reducing the energy intensity of the export of goods by rail transport?

A research hypothesis was put forward: the energy intensity of the export of goods by rail is strongly dependent on the convergence processes in the European Union, spatial proximity, and the economic situation of the importing country.

This article aims to identify linkages between the energy intensity of rail transport with spatial integration and the economic condition of countries with international trade relations with Poland (as an exporter of goods). The article uses Data Science methods with elements of spatial econometrics. A model of spatial (club) convergence and type β convergence was built for the measurement of the energy intensity of the export of goods by rail transport. The authors filled the research gap in the form by identifying the relationships between the energy intensity of goods exporting by rail transport depending on the convergence process in the European Union, the spatial proximity, and the economic situation of the importing countries. The presented approach is a novel one which addresses the energy intensity of exporting goods by rail transport and can be adapted to other modes of transport, total exportation, and in all directions to other countries.

This research is original and up-to-date in the field of transport, trade, and international business. Entities whose domains are in the above areas must respect the provisions of the sustainable development strategy and the European Green Deal. The results from the analysis of the dependence of the energy intensity of the export of goods by rail on the average distance and volume of transport may be essential for them too, but in addition, the patterns for club and type β convergences in the analyzed system of partner countries are important. Knowledge of these dependencies will rationalize decision-making processes in the context of meeting the requirements of the initiatives already taken for less energy-intensive and zero-emission transport. Currently, modern economies strive to become independent of energy imports (especially in the time of increasing conflicts); therefore, in the era of the multiplication of crises, the undertaken research brings additional cognitive values. The studies are transnational and indicate the promotion of rail transport in the entire transport system, which is important for maintaining sustainable development (in particular, minimizing the energy consumption of transport).

The article is divided into five sections. An introduction is first. In the second section, a narrative review of key issues and a body of methodological reviews on energy consumption patterns in rail transport are carried out. The research problems related to the hypothesis and purpose, the scope of the study, the data, and the methodology are described in the third section. The fourth section provides the findings of the empirical investigation and a discussion of it. Conclusions are described at the end of the article.

2. Background of Rail Transport Development

2.1. A Brief History of Rail Transport

An emblem of contemporary civilization and economic advancement was rail transport [5,19]. For one thing, it is acknowledged that the introduction of the railroad led to even greater improvements in transport. Additionally, rail transport was an example of an extraordinary development in terms of achieving cheaper costs of land transport compared to water transport [5].

Rail lines have been in use since prehistoric (ancient) times, when carts were pulled by people, horses, or gravity. In Greece, freight carts moved on tracks chiseled into the rock, and in the 16th century, Germany and other nations used wooden-railed wagonways. The introduction of the steam engine helped contemporary railroads advance more quickly. The first steam locomotive to travel on smooth tracks was created and built by Richard Trevithick in 1804 [1]. Railroad development was the fastest in Europe and the United States. All European nations developed their first rail lines (Table 1) before the end of the 19th century, and some of them were even joined into a trans-border system, demonstrating their international nature as a key characteristic [1].

Table 1. The first rail lines in European countries in the 19th century.

Country/ies	Year	First Rail Line
Czech Republic/Austria	1828	České Budějovice–Linz
France	1830	Saint-Étienne–Lyon
Ireland	1834	Dublin–Kingstown (now now Dún Laoghaire)
Belgium	1835	Brussels–Mechelen
Germany	1837	Leipzig–Dresden
Russia	1837	Tsarskoye Selo–Saint Petersburg
Netherlands	1839	Amsterdam–Haarlem
Belgium/France	1842	Mouscron–Tourcoing
Poland	1844	Warsaw–Pruszków
Hungary	1846	Pest–Vác
Spain	1848	Barcelona–Mataró
Norway	1854	Oslo–Eidsvoll
Romania/Serbia	1854	Lisava–Oravica–Bazijaš
Portugal	1856	Lisbon–Carregado
Poland/Russia	1862	Warsaw–Saint Petersburg

Source: own elaboration based on [20].

The construction of the railroad in the 19th century marked the beginning of a period in which inland transport underwent major quality progress. After the first steam locomotives were built, there was a period of rapid advancement and the introduction of cutting-edge technical solutions. Assembling techniques and the fundamental ratios between the boiler, furnace, and cylinder were prioritized in the locomotive's early stages of development, while the multiplication of power and speed was sought in later stages, which at the turn of the 19th century led to the introduction of the rail using electric and diesel traction [21]. The development of locomotives was accompanied by changes in the design of freight and passenger wagons, and the necessity to accommodate varied transport requirements prompted their specialization [22,23]. The increase in railway transport capacity was even faster, caused by the lengthening of trains, increasing the average load capacity of wagons, and the power and speed of railway vehicles. Currently, the main goal of traction vehicle

constructors is to increase energy efficiency and thus lower fuel consumption per unit of work (reduced energy consumption), which is also associated with lower emissions of toxic compounds into the atmosphere. New ideas are also being sought for how trains are driven and associated with new energy sources (alternative fuels), which are also being sought as transport technology advances [24,25]. Historically, over the centuries, the development of rail transport has faced technical, economic, ecological, and social challenges. It has been tested over time and is an example of harmonizing the dimensions of sustainable development.

2.2. Rail Transport in the Light of Sustainable Development, Energy Dependency, and COVID-19

One of modern civilization's megatrends is sustainable development, which emphasizes the need to balance social, environmental, and economic objectives [26,27]. Furthermore, it is emphasized that meeting the needs of future generations should not be viewed through the prism of their excessive consumption [28,29]. Numerous studies have addressed sustainable development and ways to reduce energy use in transport [16,30–33]. This subject is given considerable attention in an era of increasing shocks, including crises and disturbances, particularly those connected to the scarcity of energy resources [34–37]. The Sustainable Development Goals (SDGs) are a wake-up call for the world to adopt a sustainable perspective [27,38–40]. A prominent policy agenda for addressing global environmental issues and promoting sustainability is energy intensity improvement [41–44].

One of the least energy-intensive modes of transport is rail [16–18]. Despite its low energy intensity, rail transport was affected by stagnation and a fuel crisis. In the economic history of rail, there have been crises of an economic and social nature, especially fuel crises, which strengthened the stagnation of rail transport (for example, PKP Polskie Koleje Państwowe). In the 1980s, the fuel crisis limited the activity of rail transport, and the unprofitability of certain sections of rail lines was also strongly emphasized. The stagnation associated with the energy intensity of rail transport was also symbolized by the economically unjustified electrification of rail lines [45]. The harmony between the economic, social, and ecological order has been disturbed. Therefore, rail transport should be particularly important for actions aimed at sustainable transport. It is crucial to accomplishing Sustainable Development Goals and is deeply ingrained in the Sustainable Development Paradigms, such as the Shift Paradigm, Decoupling Paradigm, and Decarbonization Paradigm [46,47]. The rail system is ideally positioned to play a significant role in the development of a sustainable transport system [48]. It is important to examine the convergence of energy intensity to determine the path of sustainable development [49–53]. Originally, the convergence theory was used only to study income (e.g., GDP, value added) inequality between countries [54–56], but more and more often it refers to energy intensity [49,52]. Knowledge of the convergence of energy intensity allows for the determination of ecological constraints. This allows emerging countries to strive for a certain level of energy consumption, while developed countries can maintain a certain level of energy consumption [49,50]. Similarly, the analysis can be transferred to the consideration of the share of the transport mode in serving the needs of the economy.

However, the movement towards sustainable development is subject to constant upheavals caused by various factors, most recently by the COVID-19 pandemic. In the last years (2020–2022) of the COVID-19 pandemic, economies experienced a decrease in freight volumes (2019–2020), followed by a rebound (from 2021) [57–60]. COVID-19 has significantly affected the entire transport system [36,61,62]. However, this required calibrating the adjustment mechanism to the demand and supply patterns caused by disruptions in global supply chains [57,63,64]. Rail transport is believed to have been highly adaptable and resilient to the shocks caused by the COVID-19 pandemic. It is associated with the lever of transport during broken supply chains as a result of COVID-19 [63]. The rebuttal to the disruptions caused by the weakening of economic relations caused by the COVID-19 pandemic, but also to the downward trends in foreign trade and the rise of protectionism in Europe and the United States, was the development paradigm of "Dual

Circulation". It was related to the disconnection of internal circulation in internal economic processes from external circulation drawn by export demand [65]. Such an approach has the potential to reshape the economic model and provide a new perspective on the limits of development as seen through the lens of export-oriented growth [66,67]. Therefore, the importance of rail transport in cargo servicing has recently been raised.

2.3. Energy Consumption of Rail Transport as a Multidimensional Problem

Nowadays, the second fundamental mode of the inland transport of goods is rail. Although its significance has diminished with the growth of road transport, it is still one of the fundamental components of the European transport system [15,68].

In view of the importance of rail transport for the movement of goods, it is destined to move goods (mostly bulk) in block trains, primarily across longer distances (including international relations). Therefore, rail transport should strive to regain this market segment (bulk loads for long distances) from road transport [32,69]. Currently, rail transport is the basic link of combined transport (promoted as part of the implementation of the EU transport policy) [70].

The ongoing pursuit of measures to shift passengers and goods away from road transport and towards modes that have less of a detrimental impact on the environment, such as rail transport, is one of the cornerstones of the EU's transport strategy [47]. Furthermore, these efforts are crucial for achieving the goals of the EU's transport policy [71] and environmental policy [72].

In addition to measures aimed at a modal shift, an important element is also the calculation of the increase in the efficiency of transport in individual modes of transport. This relates to lowering energy intensity in a particular mode of transport [73–75] as well as lowering emissions of dangerous compounds into the environment [32,76,77]. Another system-wide issue for freight transport is energy security, or having access to enough energy supply at a stable price [78].

Energy intensity is a multidimensional problem in rail transport. It is understood as energy consumption by the mode of transport per unit of transport activity [79] (may be expressed in MJ/pkm for passenger transport or MJ/tkm for freight transport; for comparison purposes, tonnes or kg of oil equivalent are also used—toe/tkm, kgoe/tkm, instead of MJ/tkm). It also takes into account additional parameters other than those that are directly connected to the amount of traction fuel or traction energy consumed. Some of these elements are:

- Constructions of wagons and traction vehicles [16,80,81];
- Types of traction and propulsion vehicles [16,42,76,82], including electric [83–85], for example, cells [86–89], hydrogen [25,89–91], hybrid [92];
- Rail infrastructure [42,93–95];
- Rail traffic control systems [33,44,95,96];
- Organization of traffic and transport [33,44,88,95];
- Eco-driving [97].

In general, the multidimensionality of the energy intensity of rail transport includes organizational, technical, social, economic, and environmental factors at the level of system adaptation, governance, and the development of international relations.

2.4. Linkages between Rail Transport and Export

The growth of international trade benefits significantly from rail transport. He, Zhan, and Chen [98] looked at how it affected the export of goods with a high value-to-weight ratio. The value of Chinese laptop shipments to Europe are thought to have increased by around EUR 23.18 billion. Moreover, they stressed how intercontinental linkages gave rise to a micro-mechanism that sped up and improved export flows, making rail transport a viable alternative for exporters.

Yan et al. [8] came to the same conclusions. According to them, the "The Bet and Road" initiative's land link and rail transport (transcontinental rail) facilitate cross-border

trade between Chinese cities and other Eurasian metropolitan centers. China's exports are expanding rapidly due to the construction of new routes and the development of rail services. This mode of transport also enables the implementation of a "dual circulation" approach.

Until 2010, East Asia's international trade with Europe was carried out by the sea. Although rail connections existed, maritime transport was more competitive than rail transport in terms of cargo servicing. Only since 2011 has the potential of rail transport been noticed. The launch of the connection between Western China and Europe (Chengdu-Łódź, Chongqing-Duisburg) influenced the development of rail transport services in cities in China and the EU. These connections dynamized the market in such a way that the number of containers transported by rail on these routes doubled annually [99,100].

Rail transport was examined by Lu and Li [101] from both the supply and demand sides. They stated that on the demand side, high-speed rail boosts consumption, investment effectiveness, and export scale, which increases the production capacity of businesses.

Rao [102] examined the case of Canada in one of the earliest analyses (1978) of the connection between rail freight and exports. His study shows that one key factor influencing the demand for rail freight transport is the proportion of exports in total production. A similar line of inquiry was made using Pakistan as an example, but with the exception that the effect of international trade (the total of exports and imports) on the demand for rail freight transport was investigated [103].

Brazil is another nation that exemplifies the significance of the rail freight transport system for the development of international economic relations [104,105]. Causal relationships between rail transport corridors running in the vicinity of major economic centers and ports and trade have been noticed, which is also important for the development of production chains in the rail-intensive and export sectors. Researchers pointed out that the implementation of trade policy tools, such as the Greater Brazil Plan and National Exportation Plan, might alter the cost of transport in trade flows and improve the competitiveness of Brazilian exports [104]. From this point of view, it is worth adding that exportation can be equated with a measure of foreign demand when rail transport prices are fixed [106].

In additional research on the example of Poland by Kramarz et al. [107], the impacts of exports were not directly examined, but the focus was on the problem of the reliability of the intermodal transport network in conditions disrupted by rail freight transport. However, the research is relevant in this context, as the researchers noted that the explanation for the number of canceled trains may lie in the reasons attributable to the ordering process of re-exporting the goods. This is a valuable point worth exploring in the future.

Pittman et al. [108] examined the effectiveness of EC policies to move freight from road to rail transport. They also highlighted capacity bottlenecks in the rail sector in Poland, Slovakia, the Czech Republic, and Ukraine. The bottlenecks related to the ability of the wagons to service export and transit traffic were visible through the lost transport potential. This potential has also been lost in terms of shifting capacity (here, grain servicing) to inland waterway transport in Poland and Ukraine due to underinvestment in infrastructure. Pomfret [99] also wrote about the bottlenecks in freight rail transport in the servicing of export cargo. In the East Asia–Europe relationship, the bottleneck is the track change point on the Belarusian–Polish border. Train delays, in their opinion, result from management disruptions, not infrastructural problems. An alternative route through Lithuania to Klaipeda or Kaliningrad, and then by ship to German ports, creates incentives for Poland to improve its hinterland.

Although rail transport is not fully used in the servicing of export cargo, it is a very complex problem to be analyzed, especially in the context of the energy consumption of this mode of transport.

3. Data and Methodology

3.1. Data

The analysis employed secondary data. The data came from the databases listed in Table 2. The 2010–2020 time frame was covered. Due to the availability and integrity of

the data, this was the broadest time range that could be studied. A detailed description of the data may be found in Table 2. In order to calculate the energy consumption by rail transport, 2945 data cells were employed. The data was finally organized using panel data (154 observations). The direction of the rail exporting of goods from Poland determined the structure of the data. Poland's top 14 export destinations to European Union (EU) partners for commodities by rail transport between 2010 and 2020 have been chosen: Austria, Belgium, the Czech Republic, Denmark, France, Germany, Hungary, Italy, The Netherlands, Romania, Slovakia, Spain, Sweden, and the United Kingdom (left EU in 2020; the so-called Brexit). The study did not consider other geographic directions of exports since the available data for the remaining partner nations was only a summary (relatively small share in trade exchange).

Table 2. Description of the data used in the study.

Economic Category	Variable	Unit	Database
Export goods by rail transport	vol	volume in thousands of tonnes	[109–120]
Transport performance for export goods by rail transport	TKM	mln tkm (millions tonne-kilometers)	[109–120]
Average transport distance of 1 tonne of goods exported by rail transport	dist	kilometers	[109–120] and authors' computations
Economic growth	GDP	PPP in current international $	[121]
Energy consumption of rail transport	EC	toe (tonnes of oil equivalent)	authors' computation described in Section 3.2. of this article
Energy intensity of standard-gauge diesel traction—cargo	EI_D	MJ/thousands gross tkm	[122]
Energy intensity of standard-gauge electric traction—cargo	EI_E	MJ/thousands gross tkm	[122]
Rolling stock operation—diesel traction (freight trains)	RT_D	millions total gross tkm	[109–120]
Rolling stock operation—electric traction (freight trains)	RT_E	millions total gross tkm	[109–120]
Energy intensity of export of goods by rail transport	EI	kgoe/thousands tkm (kilograms of oil equivalent/thousands of tonne-kilometers)	authors' computation described in Section 3.2. of this article

Note: RT means rail transport. Source: own elaboration.

3.2. Methodology

The research problem was formulated in the form of three research questions:

1. Does the improvement of the economic situation of the importing country reduce the energy intensity of the Polish export of goods by rail transport to the partner country?
2. Does EU integration contribute to reducing the energy intensity of the export of goods by rail transport?
3. Is there a positive spatial effect (convergence) of reducing the energy intensity of the export of goods by rail transport?

A research hypothesis was formulated: the energy intensity of the export of goods by rail is strongly dependent on the convergence processes in the European Union, spatial proximity, and the economic situation of the importing country.

The article aims to identify linkages between the energy intensity of rail transport with the spatial integration and economic condition of countries with international relations with Poland (as an exporter of goods).

To calculate the energy intensity of the export of goods by rail transport, it was necessary to know about the energy intensity of diesel and electric traction (in MJ/thousand gross tkm) and gross transport performance separately for diesel and electric locomotives. This made it possible to estimate the aggregated energy consumption by diesel traction and electric traction using the index method. Data on the total freight transport and the

structure of the rolling stock made it possible to separate two measures of energy intensity of the export of goods by rail transport in net terms [MJ/t] from the average freight load per kilometer of the line in gross terms. The energy intensity of rail transport in net terms (hereinafter referred to as energy intensity of rail transport) was related only to the export of goods by rail transport (also taking into account the structure of exports and geographical destinations). It was necessary to estimate the energy consumption of rail transport for the export of goods for different geographical directions. This value, divided by the net transport performance for the export of goods by rail transport, and taking into account geographical relations, allowed us to obtain the energy intensity of the exportation of goods by rail transport. These operations made it possible to clean the data from the curb weight of the rolling stock. Finally, this amount was converted (change of units) into the standardized unit, such as kgoe/thous tkm.

The pre-analysis began with the analysis of selected descriptive statistics for the entire data panel and for individual countries. Then, the average annual energy intensity of the export of goods by rail was visualized on a cartogram. Data visualization allowed the identification of anisotropic spatial correlation. The last step of the pre-analysis was to investigate autocorrelation using univariate Moran's I statistics [43]. The results of the pre-analysis and the properties of the statistical features allowed for the selection of the appropriate method for the construction of the convergence model of the energy intensity of the export of goods by rail transport (Equation (1)):

$$\ln(EI_{it}) = \alpha_0 + \alpha_1 \ln\left(EI_{i(t-1)}\right) + \theta_1 \ln(vol_{it}) + \theta_2 \ln(dist_{it}) + \theta_3 \ln(GDP_{it}) + \rho \ln(WE_{it}) + \varepsilon_{it} \tag{1}$$

where:

EI_{it}—energy intensity of goods exported by rail transport from Poland to other importing countries i in year t

$EI_{i(t-1)}$—lagged energy intensity of goods exported by rail transport from Poland to other importing countries i in year t

vol_{it}—volume of transport of goods exported by rail transport from Poland to the importing country i in year t

$dist_{it}$—average transport distance of 1 tonne of goods exported by rail transport from Poland to the partner country (importer) i in year t

GDP_{it}—gross domestic product in the importing country i in year t

WE_{it}—spatially lagged energy intensity of goods exported by rail transport from Poland to other importing countries i in year t

α_i—structural parameters for endogenous variables

θ_i—structural parameters for exogenous variables

ρ—spatial autoregressive parameter

ε—random component

In the construction of the spatial weight matrix *W*, the Mahalanobis distance was used to determine the economic distance between the investigated countries importing goods from Poland by rail transport [123,124]. The model was verified on the basis of Arellano–Bond tests (AR(1), AR(2)) for the assessment of first- and second-order autocorrelation and Sargan tests for the assessment of the correctness of over-identifying conditions [125]. In addition, the normality distribution of the residuals and the significance of the coefficients were tested with the Wald test [126].

Based on Equation (1), the rate of β-type convergence can be represented as the relation [55]:

$$\beta = -\frac{1}{T} \cdot \ln(1 + \alpha_1 \cdot T) \tag{2}$$

where

T—number of years in the analyzed period

α_1—structural parameter for endogenous variables from Equation (1)

On the other hand, the length of half of the β-type convergence period can be described by the formula [55]:

$$T_{\frac{1}{2}} = \frac{ln2}{\beta} \tag{3}$$

Spatial (club) convergence can be additionally determined based on parameter ρ, and the length of half of the convergence period similarly as in Formula (3), except that parameter ρ should be substituted for parameter *β*.

Convergence can also be investigated using the stationarity testing technique [55,127]. Panel unit root tests will be used in this study, among others: Levin, Lin & Chu (LLC, common root) [128,129], Breitung (common root) [130,131], Im, Pesaran & Shin (IPS, individual root) [129], Fisher-Augumented Dickey–Fuller (Fisher-ADF; ADF-Choi; individual root) [128,132].

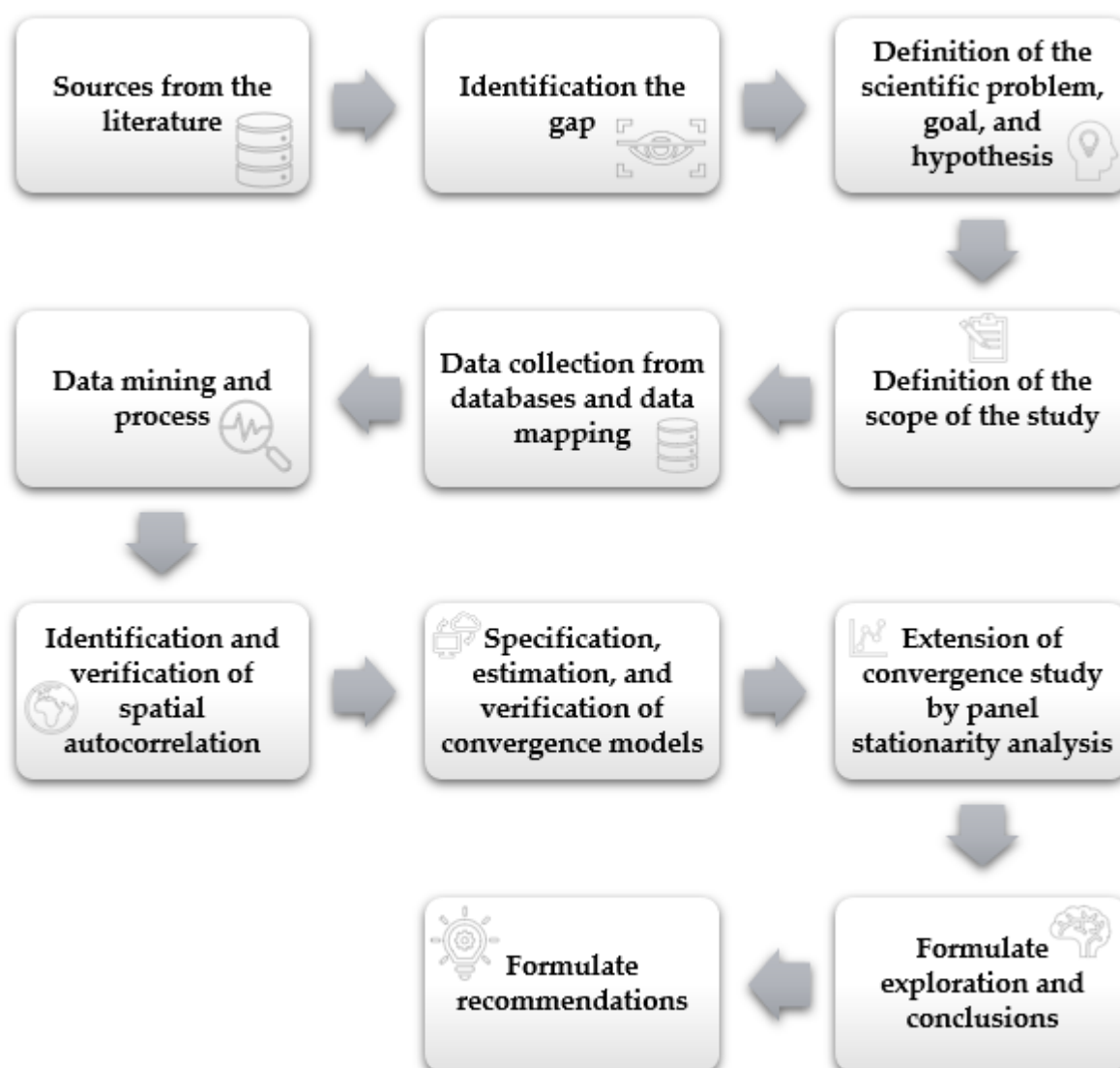Figure 1 presents the framework of the authors' research procedure (methodology).

Figure 1. The framework of the authors' research procedure (methodology). Source: own elaboration.

4. Results and Discussion

4.1. Findings and Explanations

Table 3 presents selected descriptive statistics for all observations, and Table 4 presents selected statistics for export destinations.

Table 3. Summary statistics for all observations.

Variable	Mean	Standard Deviation	Coefficient of Variation
EI	3.68	3.11	0.8472
vol	1151.40	1810.20	1.5722
dist	313.69	143.65	0.4580
GDP	1.25×10^{12}	1.21×10^{12}	0.9720

Note: For the above statistical summary, the variables that were statistically significant in the estimated model were selected (Section 4). Source: own elaboration based on data from databases listed in Table 2.

Table 4. Summary statistics by export destination.

Export Destination	Mean				Standard Deviation			
	EI	Vol	Dist	GDP	EI	Vol	Dist	GDP
Austria	10.81	1852.18	74.20	4.38×10^{11}	2.25	140.54	6.99	5.58×10^{10}
Belgium	1.83	173.74	441.98	5.30×10^{11}	0.41	88.60	64.78	6.66×10^{10}
Czech Republic	4.41	3607.45	196.71	3.69×10^{11}	1.03	1745.42	90.10	6.08×10^{10}
Denmark	2.03	170.82	400.39	2.90×10^{11}	0.44	89.02	78.91	4.05×10^{10}
France	1.91	296.91	416.34	2.79×10^{12}	0.23	150.07	48.40	3.22×10^{11}
Germany	2.06	5800.64	387.02	3.98×10^{12}	0.16	2965.35	67.10	5.16×10^{11}
Hungary	4.85	319.64	218.04	2.70×10^{11}	3.17	180.07	105.10	3.92×10^{10}
Italy	4.83	722.09	322.07	2.34×10^{12}	5.91	255.45	158.76	2.00×10^{11}
Netherlands	2.58	364.18	337.12	8.83×10^{11}	0.72	161.80	142.18	1.02×10^{11}
Romania	5.12	485.91	176.41	4.71×10^{11}	2.04	179.41	66.86	1.01×10^{11}
Slovakia	4.75	1081.91	176.86	1.58×10^{11}	1.56	384.66	41.63	1.27×10^{10}
Spain	2.50	326.18	390.96	1.67×10^{12}	1.82	177.44	118.61	1.83×10^{11}
Sweden	1.94	398.27	410.88	4.85×10^{11}	0.31	78.58	36.16	5.95×10^{10}
United Kingdom	1.83	519.27	442.59	2.79×10^{12}	0.45	282.82	54.05	3.43×10^{11}

Note: For the above statistical summary, the variables that were statistically significant in the estimated model were selected (Section 4). Source: own elaboration based on data from databases listed in Table 2.

Paying attention to the coefficients of variation contained in Table 3, it can be seen that it was relatively high for all variables. The volume of exports of goods by rail transport had the highest coefficient of variation, which fluctuated around 157%. A slightly lower share of the standard deviation in the mean value was noted for GDP and amounted to 0.972. The volatility of the state of the economy expressed as a measure of GDP is approx. 97%. Following this, it can be seen that the coefficient of variation in the energy intensity of the export of goods by rail transport for all 14 export destinations in the period 2010–2020 was approx. 85%. However, the lowest variability in the analyzed period was characterized by the average distance of transporting one tonne of goods by rail (approx. 46%). Summing up, the assessment of statistical features shows that the analyzed geographical destinations and years were not homogeneous.

The highest average value of energy intensity of the exporting of goods by rail transport in 2010–2020 was recorded for the geographical relationship Poland–Austria. It was 10.81 kgoe/thous. tkm per year. The lowest average annual value of this energy intensity was recorded in the geographic relation Poland–Belgium and Poland–the United Kingdom, at 1.83 kgoe/thous. tkm each. The value of the energy intensity of the export of goods by rail transport in Poland–Germany and Poland–France was the most stable during the analyzed period, but the most destabilized in Poland–Italy relations.

In the analyzed period of 2010–2020, the highest average annual volume of exports of goods from Poland by rail transport was recorded for Germany (5800.65 thous. tonnes), the Czech Republic (3607.45 thous. tonnes), and Austria (1852.17 thous. tonnes). The least average annual volume of exports by rail transport was recorded from Poland to Denmark (170.82 thous. tonnes) and to Belgium (173.74 thous. tonnes). The highest standard deviation, also a measure of instability, was recorded in the analyzed period in Poland–Germany (plus/minus 2965.35 thous. tonnes from an average value) and Poland–

Czech Republic (1745.42 thous. tonnes from an average value). The slightest deviation was recorded for Sweden, Belgium, and Denmark.

The smallest average distance of transporting one tonne of goods by rail was recorded in the export relation towards Austria, and the largest towards the United Kingdom and Belgium. Similarly, the smallest deviation for the average distance in the analyzed period was recorded towards Austria, and the largest towards Italy and The Netherlands. This means that Austria is a certain permanent direction for the export of goods from Poland by rail transport in the analyzed period for bulk cargo.

GDP plays an important role in the study of the economic situation of Poland's trading partners. It can be stated that the average annual GDP level in 2010–2020 was the highest in Germany and the lowest in Slovakia. Similarly, countries can be identified for the standard deviation, which is a measure of economic stabilization or destabilization.

From the perspective of the evaluated relationships with the energy consumption of commodities exported by rail transport, the aforementioned statistics imply that the tested countries—trading partners of Poland—were characterized by economic and spatial diversity.

As shown in Figure 2, it is possible to distinguish more energy-intensive directions of the export of goods by rail transport. There is a strong influence of neighborhood in individual belts. Only Austria plays the role of a hot spot and is located in the vicinity of countries that are less energy-intensive when importing goods from Poland by rail transport. Based on the arrangement of similar values in stripes, it can be concluded that there is anisotropic spatial autocorrelation, which is a function of distance and direction in space. This is consistent with the results of Moran's univariate and the average energy intensity of exports of goods from Poland by rail. The Moran I statistic is 0.3849 (Figure 3).
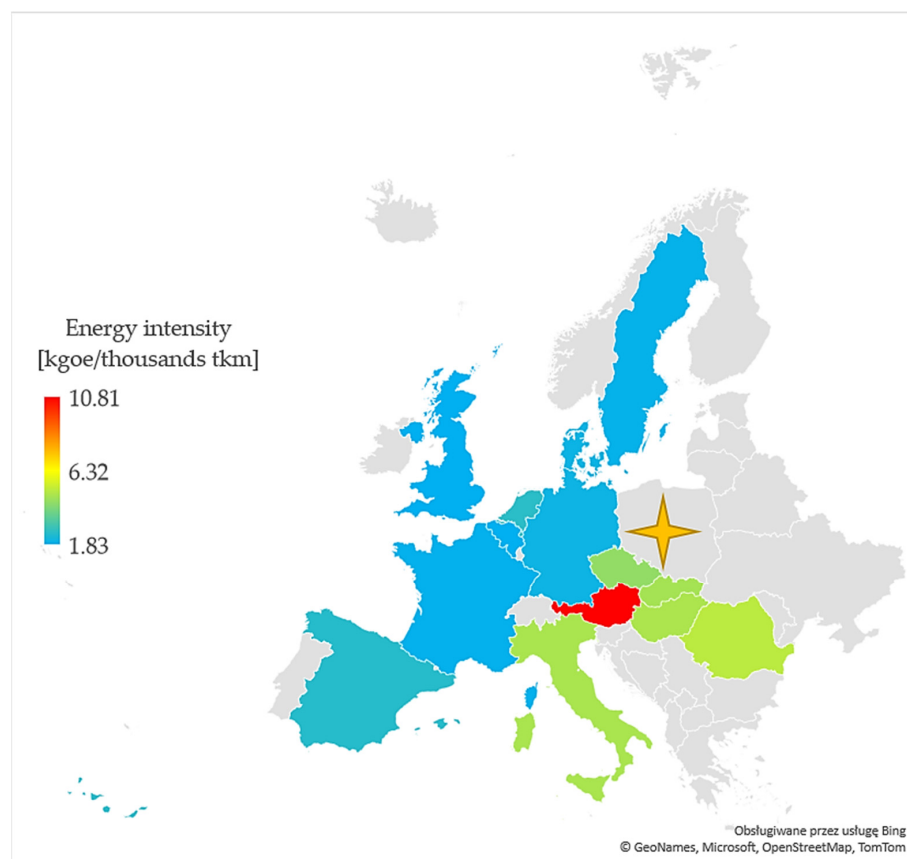

Figure 2. Average annual energy intensity of goods exported from Poland by rail transport in 2010–2020 (in kgoe/thous. tkm). Note: An asterisk indicates the exporting country (Poland). Source: own elaboration based on data from Table 4. Basemap from © GeoNames [133], Microsoft [134], TomTom [135] (by Bing [136] service, the map generated by MS Excel).
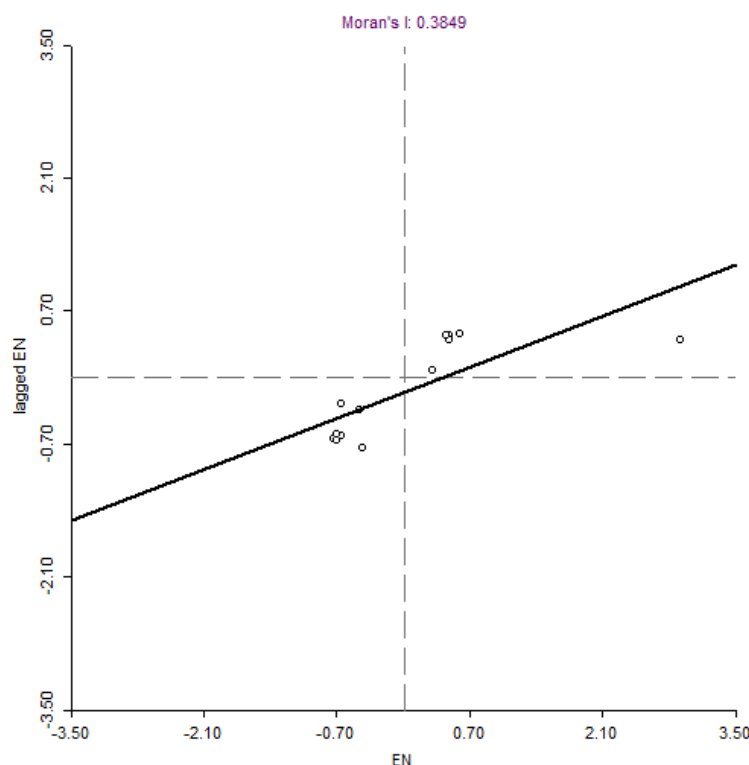
Figure 3. Moran's I for average energy intensity of export of goods by rail transport in 2010–2020. Note: the following countries are concentrated in the first quarter of the graph: Austria, the Czech Republic, Hungry, Italy, Romania, and Slovakia, and in the third quarter of the graph: Belgium, Denmark, France, Germany, The Netherlands, Spain, Sweden, and the United Kingdom. Source: own elaboration.

It can be noticed that Poland's trade partners are concentrated in the 1st and 3rd quadrants of the coordinate system. No country is an "outlier" in this case. Countries in the first quarter of the graph (Figure 3), i.e., Austria, the Czech Republic, Hungary, Italy, Romania, and Slovakia, are characterized by the fact that high values of energy intensity of rail transport in the export–import relationship correspond to large "lagging" values. Belgium, Denmark, France, Germany, The Netherlands, Spain, Sweden, and the United Kingdom are characterized by a low energy intensity of rail transport in the export–import relation corresponding to low delayed values. The above results provide a strong basis for seeking convergence in the energy intensity of the export of goods from Poland to other countries by rail transport. The results of the convergence model are presented in Table 5.

Table 5. Convergence model of energy intensity of export of goods by rail transport (β type; spatial type).

Items	Coefficient	Standard Error	z	*p*-Value	
α_0	−0.0676	0.0030	−22.9058	<0.0001	***
$\ln\left(EI_{i(t-1)}\right)$	−0.0631	0.0200	−3.1580	0.0016	***
$\ln(vol_{it})$	−0.0230	0.0095	−2.4136	0.0158	**
$\ln(dist_{it})$	−0.8492	0.0103	−82.1267	<0.0001	***
$\ln(GDP_{it})$	1.0170	0.1221	8.3318	<0.0001	***
$\ln(WE_{it})$	0.0866	0.0143	6.0409	<0.0001	***

Note: *** means statistical significance at the level of *p*-value < 1%, and ** means statistical significance at the level of *p*-value < 5%. Technique: 2-step dynamic panel, including 14 cross-sectional units; H-matrix as per Ox/DPD; asymptotic standard errors. Wald (joint) test: Chi-square(5) = 10,891.3 [0.0000] means that variables are significant in all modeled systems. Test for normality of residual—null hypothesis: error is normally distributed; test statistic: Chi-square(2) = 3.2036 with *p*-value = 0.2015 means that the null hypothesis of a normal distribution cannot be rejected. Test for AR(1) errors: z = −1.6783 [0.0933]; test for AR(2) errors: z = −3.3018 [0.0010]; Sargan over-identification test: Chi-square(44) = 12.9716 [1.0000]. Source: own calculations.

As it resulted from the model presented in Table 5, the examined variables were statistically significant in the whole system (Wald test) and separately (*p*-value for coefficients). Based on the Arellano–Bondo test, it is noted that first-order autocorrelation does not occur, whereas second-order autocorrelation does occur. Nevertheless, the Sargan test result unambiguously confirms the superindicating conditions' correctness. At the same time, based on the statistics, it can be concluded that the model had the appropriate properties.

The following relationships may be found from the coefficient analysis:

1. An increase in the volume of goods exported from Poland to partner countries by 1% will result in a decrease in the energy intensity of the exportation of these goods by rail transport by 0.023%, ceteris paribus. The elasticity of energy intensity of rail transport is 0.023 with other factors unchanged. It means that the energy intensity of rail transport is inelastic (the percentage change in the energy intensity of rail transport is smaller than the percentage change in the volume of exports). The magnitude of this flexibility may suggest that considering the criterion of energy intensity, rail transport is hardly substitutable and is used to transport specific groups of cargo at a similar volume level during the period in question (slightly changing the volume of exports by rail transport). Therefore, rail transport should be used for the transport of relatively large loads, bulk, and heavy loads (taking into account the maximization of the use of wagons [137]) instead of transport modes that are much more energy-intensive (including road and air transport) and the role of rail transport in the breakdown transport tasks in international relations should increase (in sense of an increase in the potential of rail transport) [15,108].

2. An increase in the average transport distance of one tonne of exported goods by 1% will result in a decrease in the energy intensity of rail transport by as much as 0.8492%, ceteris paribus. The elasticity of the energy intensity of this transport under the influence of changes in the average distance is much higher than under the influence of changes in the volume of exports, although it can also be described as inelastic according to the theory of economics. However, it can be said without any doubt that the long-distance export of cargo by rail reduces energy intensity to a relatively low level. At the same time, it provides the basis for the promotion of this mode of transport in long-distance international transport, especially for relatively heavy loads, bulk, heavy loads, or containers, which is in line with the sustainable development policy and the shift paradigm [15,47,138,139].

3. An increase in GDP by 1% will increase the energy intensity of the export of goods by rail transport by 1.017%. With other conditions unchanged, it can be concluded that the elasticity of the energy intensity of the export of goods by rail transport under the influence of changes in GDP is almost proportional. The energy intensity of this transport increases as much as GDP. If the GDP of individual countries increases, the socio-economic conditions of these countries improve, as well as their import possibilities. Investments increase and, at the same time, the demand for transport services increases, which creates an increase in transport activity in various directions. This generates more and more energy intensity of transport if it does not go hand in hand with technological progress.

Moreover, in the presented model, there are two types of convergence of energy intensity of the export of goods by rail transport: spatial (club) and β-type.

The rate of convergence of energy intensity of the export of goods from Poland using β-type rail transport is 10.77%. This means that the level of the energy intensity of the export of goods by rail transport from Poland between importing countries is equalized at the rate of 11% per year. The period after which this convergence will be halfway between the initial state and the point of long-term equilibrium is 6 years and 5 months (half-life time). This convergence takes into account only the dynamics of changes in energy intensity; therefore it seems that a more complete picture is provided by spatial convergence.

Spatial (club) convergence is understood as the occurrence of a group of influences that shape the dynamics of the energy intensity of the export of goods by rail from Poland

to other countries in a similar way in neighboring facilities. However, the proximity does not have to be purely geographical [55], because the measure of the distance between the examined spatial units is the difference in shaping the level of energy intensity. The basic convergence of this type includes trade in goods and services, the interpenetration of spatial effects, and capital migration. In addition, club convergence takes into account the diversity of points of long-term equilibrium, which have their source in the occurrence of scale effects, unevenly distributed production factors in space, different stages of development of individual countries, or the occurrence of the unreliability of the market mechanism (occurrence of public goods, externalities or asymmetry of information). It was possible to investigate this by taking into account the phenomenon of spatial autocorrelation in the model. The rate of spatial (club) convergence is 8.66%, whereas the period after which this convergence will be halfway between the initial state and the long-term equilibrium point is 8 years.

Table 6 presents an unconventional approach to convergence identification, based on stationarity analysis.

Table 6. Convergence study by panel stationarity analysis.

Test	E_{it}			$\ln(E_{it})$		
	Individual Intercept	Individual Intercept and Trend	None	Individual Intercept	Individual Intercept and Trend	None
Levin, Lin, Chu (common root)	−14.1331 [0.0000]	−17.9370 [0.0000]	−3.1692 [0.0000]	−8.7521 [0.0000]	−10.5778 [0.0000]	−3.4498 [0.0003]
Breitung (common root)	-	−1.6760 [0.0469]	-	-	*−1.3401* *[0.0901]*	-
Im, Pesaran and Shin (individual root)	−5.4532 [0.0000]	−2.7863 [0.0027]	-	−3.9874 [0.0000]	*−1.5734* *[0.0578]*	-
ADF-Fisher (individual root)	77.6241 [0.0000]	59.1156 [0.0005]	41.9663 [0.0437]	67.3814 [0.0000]	51.4562 [0.0044]	47.8606 [0.0111]
ADF-Choi (individual root)	−4.4376 [0.0000]	−2.9584 [0.0015]	−2.1482 [0.0158]	−3.8674 [0.0001]	−2.4212 [0.0077]	−2.5094 [0.0060]

Note: The *p*-value is given in square brackets. Statistically insignificant results at the level of *p*-value < 5% are marked in italics. Source: own calculations.

Table 6 clearly shows that regardless of the method of identification or estimation of the pace of convergence, it undoubtedly occurs, as evidenced by the analysis of the stationarity of the panels. Based on the tests of LLC, Beitrung, IPS, Fischer-ADF, and ADF-Choi, it should be recognized that there is convergence in the analyzed panel. In other words, the differences in the levels of energy intensity of rail transport in the export of goods from Poland to the 14 analyzed countries of the European Union are becoming blurred. The common EU policy and the adopted railway packages contribute to this [9,10,12,15,71]. It is also a confirmation that this is a case of club convergence [127]. This means that EU integration is conducive to reducing the energy intensity of the export of goods by rail transport.

4.2. The Role of Rail Transport in Combined Transport in the View of Technological Evolution

It is undeniable that rail transport is a mode of transport with low energy intensity compared to other modes (e.g., road or air transport) and it has the potential to reduce the energy intensity of the entire transport sector (e.g., through the implementation of the EU Shift-to-Rail program). The presented research results indicate the course of the convergence (polyconvergence) process in the EU regarding the energy intensity of the export of goods by rail transport. The study considers spatial and economic factors in a dynamic approach at the megaeconomic level. However, this approach could be extended, beyond the analysis of rail transport itself, in consideration of combined transport in a wider dimension. The research results are complemented by a discourse on the role of rail transport as part of combined transport in light of technological progress from the point of

view of economic benefits and limitations. Combined door-to-door transport significantly outperforms its single-modal alternative to road transport (Euro 6) in terms of energy efficiency. In recent UIRR studies, an increase in savings of 40–70% and a decrease in carbon footprints of 60–90% have been noted [140]. In the case of classic rail–road transport, the advantage of transport only by road in terms of flexibility, accessibility, or directness is indisputable. The solution is to promote and implement rail–road transport as the essence of combined transport (understood by the EU definition) to a broader extent. In addition to the requirements resulting from the definitions, attention should also be paid to such elements as:

- IT and telematics solutions (e.g., electronic documentation, tracking of shipments, motor vehicles, trains, wagons, etc.);
- Optimization of travel routes to/from the terminal from/to the client, dynamic response to changing conditions on the route (road transport);
- Optimization of the time of changing the means of transport by the load unit in rail–road terminals, which requires good work organization both on the side of carriers (rail and road) and the terminal;
- Appropriate technical speeds of freight trains—especially fast freight trains running between terminals (depending on the condition of the rail infrastructure, condition of railway traffic control (RTC) devices, and condition of rolling stock);
- Appropriate commercial speeds for freight trains; proper organization of freight transport understood also through the prism of shuttle transport between terminals without unnecessary stops along the route, including railway lines dedicated (or with preference, e.g., at night) to freight transport;
- Good synchronization of the time of arrival at the terminal with departure (truck → train, train → truck)—elimination or minimization of possible temporary storage of load units.

The efficiency of transshipment terminals is influenced, among other things, by the modernity of transshipment equipment, the level of digitization, and the connection of the terminal infrastructure with the lines of the TEN-T network [140].

The fundamental presumptions underlying the growth of rail–road transportation include [141]:

- A rise in the need for transport, accompanied by difficulty in supplying that need alone by road transportation;
- The need to protect the environment (including reducing energy consumption), which determines the directions of development of the economy and transport;
- Shifting the weight of transportation demands (user preferences)—raising the significance of timeliness and flexibility;
- The deterioration of the quality of road transport services, as well as the rising costs of congestion;
- Development of multiple forms of combined transport, e.g., transport of swap bodies, semi-trailers, and containers; transport of full motor vehicles (ro-la), bimodal transport (allows you to select the best option based on the size of the load lot, company fleet, transport distances, and other characteristics).

The International Union for Road-Rail Combined Transport (UIRR) points to numerous positive effects of door-to-door combined transport [140]:

- Reducing the dependence of European economies on energy imports;
- Reduction of the carbon footprint to 90% generated by land freight transport;
- Easing traffic congestion by shifting freight from road transport to rail transport;
- Mitigation of harmful emissions of noise, particulate matter, and other environmental pollutants;
- Mitigation of road infrastructure degradation.

Wojewódzka-Król [141] emphasizes that the problem of the profitability of combined transport is debatable. The benefits obtained depend primarily on the conditions of their implementation and the preferences of customers (society). However, it points to the

benefits for the customer, road haulers, rail, and the environment. A well-functioning combined transport system can be advantageous for [141]:

- The customer through greater punctuality, and transport time comparable to road transport, ensuring door-to-door transport and greater reliability;
- Road haulers by making more efficient use of transportation means; intermodal unit is transported by rail and road vehicles can be used for other short-distance transport; labor savings;
- The rail transport by providing more rail freight volumes, enabling shorter turnaround times for block trains;
- The environment (from the point of view of external cost [142]) by reducing road traffic, energy intensity, air pollution, noise, and land use; increasing safety.

However, the barriers to the development of combined transport are still as follows: an insufficiently developed network of terminals, infrastructural barriers (determining the speed of trains), lack of rolling stock, lack of sufficient incentives to use this technology, and instability of the intermodal relief (a financial tool reducing the fee for access to railway infrastructure for intermodal transport) [141,143].

In addition, UIRR noticed the interpenetration of six global orders important for international business, trade, and logistics [140]:

- Energy crisis and EU independence;
- European Green Deal;
- European Climate Law;
- Strategy for Smart and Sustainable Mobility;
- Climate change;
- War in Ukraine.

There are eight lines of action and initiatives related to the above-mentioned global orders [140]:

- Digital transformation (en13044 revision; EDIGES; TAF TSI revision; eFTI Regulation; ILU-Code; ILU-Register (FENIX Project));
- Environment and decarbonization (CESAR; KV4.0; CT4U campaign);
- Dangerous goods and waste transport (Waste Shipment Regulation; Digital Automatic Coupling for intermodal wagons; COTIF/RID);
- CT Assets (AEROFLEX Project; Weights and Dimensions);
- EU road haulage rules (ERA Register for Infrastructure (RINF); Q-ELETA Project; Digital Train 2.0; Rail Freight Corridor Regulation; Eurovignette Directive);
- Rail freight: infrastructure and quality (TEN-T Regulation Track Access Charging; Regulation on waiving of track access charges; state aid guidelines);
- Transshipment terminals (crisis management (Danish safety incidents; LL block issues; rail traffic disturbances; Ukraine war effort); ERA Intermodal Task Force; CACTUS Project; EU railway standards);
- Intermodal transportation (RNE WG on Combined Transport; PLANET Project; Combined Transport Directive; Rail Facilities Portal).

The technological evolution of the rail transport system has been achieved, among others, by [140]:

- The Action Digital Train 1.0—makes it possible to identify the benefits of mining data on the composition of the train and the train's course; enables the calculation of the estimated time of arrivals (ETAs) based on artificial intelligence;
- The Action Digital Train 2.0 (continuation of 1.0)—aims to integrate all stakeholders interested in the development of the Q-ELETA Quality Management System (QMS) for European combined transport operations; Q-ELETA will increase predictability and punctuality in the long term;
- Project COMBINE—the aim was to assess the potential of combined transport in the Baltic Sea region; the final task was to create a database of national regulations for combined transport;

- The aim of the H2020 project AEROFLEX was to develop and demonstrate new vehicle technologies and architectures with optimized aerodynamics, powertrains and safety systems, and flexible load units. As part of this project, load tests were carried out on four different rail systems and tests for deformation or other damage; one of the goals was to achieve energy savings of 4–5% by using separate platforms [144];
- FENIX (European Federated Network of Information eXchange in LogistiX)—the goal is to develop, implement and validate digital information systems along the EU transport Core Network. The aim was, inter alia, to facilitate cross-border rail freight transport through eCMR (paperless transport in intermodal transport with the possibility of exchanging road–rail documents; e-Gate (technology that improves the data exchange gate in the terminal/hub, also at the level of the ILU code register); e-FTI (Business-to-Administration (B2A) digital communication tool) [145,146].

Positive effects are also evidenced by the expansion of UIRR membership, e.g., accession of PCC Intermodal from Poland, Delta Rail from France, or Railhub Transylvania from Romania, which means that they respect the goals related to reducing the energy intensity of the transport sector and the concept of zero-emission transport.

5. Conclusions

The presented research allows for the assessment of the convergence process in the EU about the energy intensity of the export of goods by rail transport due to geographical proximity and the economic situation of Poland's trading partners (importers). An anisotropic spatial correlation was identified, which is a function of not only distance but also the direction in space. This means that the convergence process has a spatial (club) and dynamic character, the so-called polyconvergence. The occurrence of type β and club convergence was verified, with its pace assessed at the level of 8.66% per year. The half-life of the disappearance of differences between the examined destinations in terms of the energy intensity of the export of goods by rail is 8 years (from the starting point to the long-term equilibrium). However, without taking into account the spatial and economic distance, in relation to dynamic processes only, convergence would last for a shorter time. Its rate would be 10.77% (half-life time is equal to 6 years and 5 months). In addition, a proportional elasticity of the examined energy intensity under the influence of changes in GDP was noticed. Economic growth results in an identical percentage increase in the energy intensity of export by rail transport from Poland to the examined destinations. This is a signal that the parameters and quality of infrastructure must be improved by investing in infrastructure. In addition, a stronger sensitivity to the energy intensity of the exportation of goods by rail was noticed under the influence of changes in the average distance than under the influence of changes in the volume. This confirms that servicing bulk loads, heavy or relatively large, over long distances by rail transport decreases the energy intensity of rail transport. This approach will relieve the entire transport system in terms of energy efficiency by shifting the servicing of this type of cargo from road transport to rail transport. At the same time, the study is important from the point of view of transportation policy, as it indicates that the common EU policy in the field of shaping transport brings positive results (integration and convergence takes place), but at the same time confirms the legitimacy of the shift of paradigm in sustainable transportation policy.

The research results entitled formulation of several key recommendations for practice, which, when implemented in economic reality, will contribute to obtaining added value and economies of scale:

1. Increasing the share of rail transport in transport chains [147–149] (intermodal transport; consultations in Poland are currently underway on the program "Directions of development of intermodal transport until 2030 with a perspective until 2040" [150]—its purpose is to identify the directions of development of transport and financing needs from the perspective of 2021–2027).
2. Providing synchromodality to these chains (Synchromodality as a Service (SaaS)) [151–153].

3. Increasing the speed of freight trains by adapting the lines to higher speeds; lines dedicated to freight transport [154] (example of Betuwe in The Netherlands [155]).
4. Increase in productivity and decrease energy intensity (longer and heavier trains) [156].
5. Improving access to seaports and border crossings (in the East) as generators of the main traffic of international transport [64,157].
6. Accelerating the deployment of new interoperability technologies (ERTMS, track and trace, etc.) [13,158].
7. Automation of transshipments in terminals (among others, Internet of Things (IoT) systems) [159–161].
8. Customer orientation, attracting new customers from newly developing industries [162,163].
9. Innovative solutions (EU program Shift to Rail (S2R) under Horizon 2020) [164,165].
10. Information sharing and joint bug fixing—affect development, reliability, and punctuality (especially in sense of open access to the Single European Rail Area (SERA)) [166].

The aim of the article has been achieved, and the research hypothesis has been verified. The research results prove that this is an area of research worth deepening due to the groups of cargo being extended to other destinations and the division into various modes of transport.

The limitations of this study result from its assumptions and the data used (during the analyzed period last year, the United Kingdom withdrew from the EU, the so-called Brexit). Data in 2020 may be affected by the global COVID-19 pandemic. The energy intensity of the export of goods by rail transport from Poland may also be affected by the following: structural, supply, and price shocks, as well as other changes of a social, political, and economic nature, which were not quantified and included in the study (it was not possible to include them due to the insufficient number of degrees of freedom and other properties of statistical features). Therefore, in future research directions, it is worth paying attention to decomposition analysis and the exploration of shocks with the above background, extending the time range of the study. It is also worth considering the analysis of business cycles and the leakage of shocks. Future research directions may also include a division into groups of cargo and directions of export dedicated to them. Undoubtedly, a valuable contribution to future research is the development of a model for intermodal transport at a lower level of data granulation, taking into account the directions of transport and locations of intermodal terminals. Sigma convergence (with a strong emphasis on in-depth taxonomic analysis) also is still worth exploring.

The conducted research is innovative, as so far in the analyzed literature there are no studies that take into account the energy intensity of transport in this approach, through export–import relations and in relation to rail transport. Usually, the role of transport in the flow of goods and services for export–import relations and dependence on energy carriers is described, but no attempt is made to assess this convergence. These studies are interdisciplinary and cover many research areas, including management, economics, socio-economic geography, statistics, econometrics, and computer science. The research results can be useful for transportation policymakers, infrastructure operators, decision-makers in economic management, or scientists.

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Data Availability Statement: Data are contained within the article or supplementary material. To estimate the analyzed results, the authors used raw data from the databases included in Table 2. To generate the map, the authors used a basemap from the sources indicated below Figure 2.

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