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The Pattern of Road Freight Transport Services in Europe: The Role of Central and Eastern European Countries

Struktura usług drogowego transportu towarowego w Europie. Rola krajów Europy Środkowo-Wschodniej

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Abstract

This paper analyses the factors shaping the structure of European road freight transport (RFT) services exports. The RFT sector, primarily composed of small firms, is vital to the European economy. We employed Poisson regressions to provide a pioneering estimate of a structural gravity model for RFT services from 2012 to 2019. Our findings indicate that RFT exports are strongly correlated with gravity variables such as the GDP of trading countries, distance, contiguity, and road infrastructure. Exports are also linked to business cycles, personnel cost differences, the size of RFT firms, and the Services Trade Restrictiveness Index (STRI). Our analysis focuses on Central and Eastern European (CEE) countries, which have maintained a high share of the RFT market since joining the EU, as evidenced by their high Revealed Comparative Advantage (RCA). The strong position of CEE countries can be attributed to lower personnel costs, the expansion of Global Value Chains (GVCs), and the significant potential of RFT firms operating in these countries.

Słowa kluczowe:
model grawitacyjny, usługi, Europa Środkowa i Wschodnia, UE, drogowy transport towarowy

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Streszczenie

Naszym celem jest analiza czynników wpływających na strukturę eksportu usług europejskiego transportu drogowego towarów (RFT). Sektor RFT, składający się głównie z małych firm, ma kluczowe znaczenie dla gospodarki europejskiej. Przeprowadziliśmy regresję Poissona do pionierskiego oszacowania strukturalnego modelu grawitacyjnego usług RFT w latach 2012–2019. Wyniki dowodzą, że eksport RFT jest silnie skorelowany ze zmiennymi modelu grawitacji, takimi jak PKB krajów handlujących, odległość, wspólna granica i infrastruktura drogowa. Ponadto pokazaliśmy, że eksport jest powiązany z cyklami koniunkturalnymi, różnicami w kosztach personelu firm transportowych, wielkością firm RFT oraz wskaźnikiem restrykcyjności w handlu usługami. Nasza analiza koncentruje się na krajach Europy Środkowo-Wschodniej, które od czasu przystąpienia do Unii Europejskiej mają wysoki udział w rynku RFT, o czym świadczy ich wysoka przewaga komparatywna. Silną pozycję krajów Europy RFT można przypisać niższym kosztom personelu (kierowców), rozwojowi globalnych łańcuchów wartości oraz znacznemu potencjałowi firm RFT działających w tych krajach.

Introduction

The road transport sector is the bloodstream of the European economy. It has become a crucial component of the European Union (EU) common market, accounting for approximately 75% of all transport services. According to Eurostat, in 2017, the sector comprised more than 570,000 companies and employed over 3.3 million people [**De Smedt, De Wispelaere, 2020**]. Of these, more than 103,000 firms were active in Spain, representing 18% of all EU-28 companies. A significant proportion of firms were also located in Poland (15%), Italy (11%), and the United Kingdom (8%). In other Member States, the number of active companies in this sector was relatively small.

The geographical structure of the European road freight transport (RFT) market is complex. However, there are no comprehensive econometric studies analysing this structure within the EU. Our paper offers a pioneering analysis based on the structural gravity model.

The sector's dynamic development has been driven largely by the deepening of EU integration. The creation of the Single European Market (SEM) in 1992 gradually eliminated technical and fiscal barriers and expanded international merchandise trade among EU members. The removal of border controls and the free movement of people within the Schengen area further facilitated intra-European road freight transport. In addition, up to 30% of the EU budget was allocated to structural policies, especially in the less developed members of the EU. Much of this funding supported the development of road and highway infrastructure in southern EU members (Greece, Portugal, and Spain) and Central and Eastern European (CEE) countries, which joined the EU in 2004–2007. Foreign direct investment (FDI) from older member states facilitated industrial growth in the CEE region, providing additional stimulus for trade expansion between "old" and "new" EU members.

Following EU accession, CEE countries rapidly expanded their international road transport services. They became major exporters of road transport services, with high levels of Revealed Comparative Advantage (RCA), and emerged as active providers of cabotage services, particularly in large neighbouring European economies.

The fragmentation of production processes contributed to globalisation during the 1990s and throughout the 2000–2020 period. Many studies have documented the rapid expansion of Global Value Chains (GVCs), which increased the volume of goods traded among international companies and local suppliers and, in turn, heightened demand for transport between industrial centres and European ports.

Road transport guarantees door-to-door delivery, which is essential for most industrial (GVC) and wholesale clients. However, the continued growth of the transport sector has generated harmful externalities, including air pollution, traffic congestion, and road accidents. These challenges have increased pressure on EU policy makers to implement more restrictive CO_2 emission standards and to promote rail and water transport, which requires investment in multimodal logistics centres.

The large number of relatively small firms operating in the sector creates an almost perfectly competitive market structure. While this structure has advantages, it also has drawbacks that became evident during the pandemic and economic downturns. Small and medium-sized enterprises (SMEs) have limited resources and borrowing capacity and are generally more vulnerable to market disruptions. Persistent demand for low-priced goods increases pressure on drivers' wages, reducing the attractiveness of the profession and encouraging firms to "flag out" or engage in fraudulent and illegal practices. As a result, the sector faces serious challenges.

Several studies have analysed the dynamics and characteristics of the European road transport market. The most comprehensive quantitative study, "Road freight transport in the EU: In search of a balance between the economic and social dimension of the internal market," was authored by **De Smedt and De Wispelaere [2020]**.[1] The researchers examine the characteristics of companies and employment in the sector, the dynamics of domestic and international road transport services, and factors such as personnel costs—associated with the foreign penetration of the sector and bilateral service flows between selected economies.

[1] The report was compiled as part of the "The Road to Transparent and Fair Remuneration and Working Conditions in the Transport Sector (TransFair)" project, funded by the European Commission, DG Employment, Social Affairs and Inclusion.

However, to the best of our knowledge, no synthetic econometric analysis explains the geographic structure of RFT services among European countries. In our paper, we apply, for the first time, the structural gravity model to analyse the determinants of RFT service exports. While the gravity model is commonly used to study international trade flows, it has been applied to trade in services far less frequently due to the scarcity and low quality of data. Some studies have applied this methodology to total trade in services—e.g. **Grünfeld and Moxnes [2003]**, **Kimura [2003]**, **Kimura and Lee [2006]**. We select explanatory variables based on the gravity model while taking into account the specific characteristics of the RFT sector. These variables include the GDP of trading countries, bilateral distance, road infrastructure, common border, language, and existing trade barriers (STRI). Additionally, we consider business cycles in trading nations, differences in personnel costs, and the size of RFT firms.

Our analysis focuses on CEE countries, which have captured a large share of the RFT market since joining the EU. The strong position of these countries can be attributed to lower personnel costs, the expansion of GVCs, and the substantial capacity of RFT firms operating in CEE countries.

The paper is organised as follows: In the second section, we review the literature. In the third, we explain the selection of independent variables and outline the study's methodology. In the fourth section, we present and discuss the empirical results. The final section concludes and summarises the main findings.

Review of literature

The liberalisation of trade and road transport, resulting from the creation of the Single European Market in 1992, reduced trade costs and contributed to the expansion of trade between member countries. In the long run, integration contributed to a better allocation of capital, i.e., more efficient investment favouring specialisation and a larger volume of output (economies of scale), thus resulting in lower unit costs. These benefits can be achieved in a large, integrated European market. Through increasing competition in a common market, integration led to lower prices and a greater variety of goods available to consumers. The trade implications of the creation of the SEM are reviewed comprehensively, e.g., in **Spornberger, J. [2021]**, **t'Veld [2019]**, and **Michałek et al. [2015]**. The introduction of the Service Directive, also known as the Bolkestein Directive [**European Commission, 2006**], marked a further step in the liberalisation of service flows, contributing to the expansion of trade among EU countries [**Kox, Lejour, 2006**]. Moreover, eliminating border controls and the free movement of people within the Schengen area facilitated the expansion of intra-European road freight transport. The implications of various elements of EU integration have been studied, e.g., by **Felebrmayr [2022]**.

The European Conference of Ministers of Transport (ECMT) regulates access to the road transport market. Since 1974, the ECMT has operated a quota system that grants multilateral authorisations. ECMT licences are obligatory for the operation of road haulers between member states [**International Transport Forum, 2020**]. They enable heavy goods vehicles to carry out unlimited multilateral freight operations. The introduction of quotas was aimed at the gradual liberalisation of road freight transport and the harmonisation of competitive conditions. The ECMT has also introduced standards on exhaust emissions. These standards and safety requirements for vehicles ensure gradually cleaner and safer vehicles. In 2015, ministers approved a quality charter for road freight transport operations under the ECMT quota system, which sets qualification standards for companies, managers, and drivers. The Quality Charter entered into force on 1 January 2016.

The size and quality of road infrastructure corresponds with a country's ability to provide road freight services at home and in other countries.[2] The EU's economic, social, and territorial cohesion policy (so-called structural policy) is a crucial element in promoting economic convergence among member states and is particularly important for the southern and CEE member states. Since the late 1980 s, about one-third of the EU's budget has been earmarked for structural policy. A large share of this funding (up to 40% in some cases)

[2] **Gavurova et al. [2023]** show that there is also a relationship between road transport development and the expenditure of tourism visitors.

is allocated to the development of transport infrastructure in southern and eastern member states. For example, in Poland, there were practically no highways before the country's EU accession in 2004. By the end of 2020, around 1,750 kilometres of highways and expressways had been built, with most of these projects co-financed using EU structural funds. Structural policies have also helped finance the modernisation of the country's regional roads and railway tracks. Structural fund transfers from the EU budget to Poland amounted to EUR 110.6 billion between May 2004 and April 2024 [**Michałek, Hagemejer, 2024**].[3]

The accession of CEE countries to the EU in 2004 expanded trade flows between the east and west in terms of both final and intermediate goods. For example, **Martínez-Zarzoso et al.** [**2020**] estimated that the 2004 eastward enlargement increased bilateral trade by 28% for final goods and 24% for intermediates. Most of these new trade flows were handled by road. International road freight transport represented about 33% of total road services in the EU-28 from 2008 to 2018 [**De Smedt, De Wispelaere, 2020**: 35].[4]

In another paper, **Grančay et al.** [**2015**] studied post-accession trade convergence within the EU-15 and between CEE countries. They confirmed convergence in trade levels per capita but noted divergence in geographical and commodity trade structures. This may suggest that multinationals have adjusted their production structures within the EU to reach economies of scale through specialisation and establishing EU-wide value chains (GVCs).

CEE countries are also actively participating in GVCs; they rapidly increased their involvement in European GVCs, organised by international firms. This trend was well documented by **Taglioni and Winkler** [**2016**]. The foreign value added in gross exports in 2011 was higher in the Czech Republic, Slovakia, Bulgaria, Slovenia, and Estonia than in Denmark, Sweden, Austria, Germany or France [**Taglioni, Winkler, 2016**, Fig. 4.8].[5] The fragmentation of production processes, organised mainly by the German economy, has increased the participation of other EU countries in European GVCs and created additional demand for road transport services.

* * *

Data on road freight service exports in Europe are presented in Table A1 in the Appendix. The largest exporters of these services in 2022 were Poland, the Netherlands, Germany, and Spain. Among these countries, Poland demonstrated the highest dynamics of exports in the 2014–2022 period and a large share of the EU market. Some other CEE countries, such as Slovakia, Lithuania, Romania, and Slovenia, were also characterised by high growth rates, however their shares in the European market were much lower.

The structure of European road transport services reflects the sector's unique characteristics and the specific features of EU economies. Many small companies in this sector own or lease haulers. The average number of trucks per company was 7.6 in the EU-28 in 2017 [**De Smedt, De Wispelaere, 2020**: 45]. These numbers were lower in the case of major exporters of road freight services (Lithuania: 4.0, Latvia 5.5, Netherlands 6.1, Poland 7.8) in comparison to large importing countries such as France (10.8), Belgium (13.0) and Germany (14.7). A precise, up-to-date description of the firms' characteristics in individual countries is not very easy since there are important differences between the Eurostat and Orbis databases. The Eurostat data in principle covers all companies active in a given country, while the Orbis database covers only some companies, though provides much more detail about their characteristics. In the case of some countries, such as Spain, the differences in the number of companies between the two sources are very large.

In almost all empirical studies analysing merchandise exports, larger companies are more productive and export-oriented than smaller ones. This reflects economies of scale and the application of modern technologies, which are crucial in the case of material production (see, e.g., **Armenter, Koren** [**2015**]).

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3 This is not a net transfer because Poland also paid EUR 86.3 billion to the EU budget. But it was an important source of co-financing for Poland's road infrastructure.

4 From 2009 to 2018, EU-28 national transport grew by 7.3% and international transport by 26.0%, pointing to a growing importance of international transport [**De Smedt, De Wispelaere, 2020**: 34].

5 CEE countries had also higher indicators of Foreign Value Added Embodied in Domestic Final Demand in comparison to EU-15 members [**Taglioni, Winkler, 2016**, Fig. 5.12].

However, this relationship appears less pronounced in the case of road transport companies. The existence of many small export-oriented companies probably means they use similar technology (owned or leased haulers). The introduction of stricter standards and safety requirements, including driver working-time monitoring, ensures that vehicles are cleaner and safer, and that companies have to use similar truck technology. Small and medium-sized companies (SMEs) may face comparative disadvantages in terms of logistics and brand recognition, but the expansion of electronic intermediary platforms for delivering goods facilitates access to transport services for small companies. Consequently, the relatively small average size of companies does not diminish the potential comparative advantage of the road freight sector in a given country. Data on the Revealed Comparative Advantage (RCA) of selected European countries are shown in Table 1.

Table 1. Revealed Comparative Advantage (RCA) of selected European countries in road freight services, 2004–2022

Country	2004	2008	2010	2014	2016	2018	2020	2022
Belgium	1.9	1.1	1.3	1.2	1.2	1.2	1.1	1.1
Bulgaria	1.8	2.5	2.2	2.0	2.1	2.0	2.6	2.3
Czech Republic	3.7	3.5	3.8	3.2	3.2	3.2	3.0	3.0
Denmark	2.2	1.4	1.1	1.0	1.1	1.0	1.1	0.8
Germany	0.8	0.2	0.2	0.3	0.3	0.3	0.2	0.2
Estonia	2.1	.	.	1.9	1.8	1.9	1.7	2.1
Ireland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Greece	.	.	.	0.2	0.1	0.1	0.1	0.1
Spain	.	1.4	1.4	.	.	.	.	.
France	.	0.8	1.1	0.6	0.6	0.6	0.6	0.6
Croatia	0.6	0.6	0.7	0.7	0.9	0.8	1.1	0.7
Italy	0.6	0.7	0.7	0.4	0.4	0.3	0.3	0.4
Cyprus	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Latvia	3.5	3.8	3.7	4.4	4.2	4.0	4.1	4.2
Lithuania	7.2	9.3	9.8	7.3	7.3	8.0	8.7	8.5
Luxembourg	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.6
Hungary	.	1.7	2.0	1.8	1.5	1.3	1.4	1.2
Malta	0.0	0.0	0.0	0.0	.	0.0	0.0	0.0
Netherlands	0.5	1.4	.	1.2	1.2	1.2	1.2	1.3
Austria	.	.	.	3.2	3.4	3.3	3.3	3.5
Poland	4.3	5.1	4.9	4.1	4.1	4.1	3.9	4.1
Portugal	1.6	1.6	1.6	.	.	.	.	.
Romania	8.6	3.8	4.5	5.5	6.2	6.3	5.7	5.5
Slovenia	3.9	3.7	3.9	2.9	3.5	4.4	4.8	4.2
Slovakia	.	3.0	1.7	3.7	3.9	3.8	3.7	3.7
Finland	.	0.2	.	0.0	0.6	0.6	0.7	.
Sweden	1.3	1.4	0.9	1.1	0.8	0.8	0.7	0.8
Iceland	.	.	.	.	.	0.0	0.0	0.0
Norway	0.2	0.3	.	.	.	.	.	.
Switzerland	.	.	.	.	.	.	.	.
United Kingdom	0.3	0.2	0.2	.	.	.	.	.
Montenegro	.	.	0.5	3.6	3.2	3.5	4.3	3.8
North Macedonia	3.8	5.5	7.1	0.6	1.0	0.7	1.7	0.9
Türkiye	1.1	1.4	1.6	4.3	4.9	5.0	4.8	4.6
Albania	.	.	.	0.0	0.2	0.4	0.2	0.4
Serbia	.	.	.	2.4	1.1	2.3	1.9	1.7
Kosovo	.	.	.	.	.	.	.	.
Bosnia and Herzegovina	.	.	.	0.0	0.0	0.0	0.2	0.2

Source: Own calculations based on Eurostat data. The data for the 2004–2013 period are based on BPM5, while the data for 2014–2022 are based on BPM6. The RCA is calculated as the Balassa index. Some countries such as Spain, Portugal, Norway and the UK do not provide relevant data.

Table 1 shows the road transport sector's relative position in comparison to other European countries. The RCA index was calculated as the Balassa index, that is

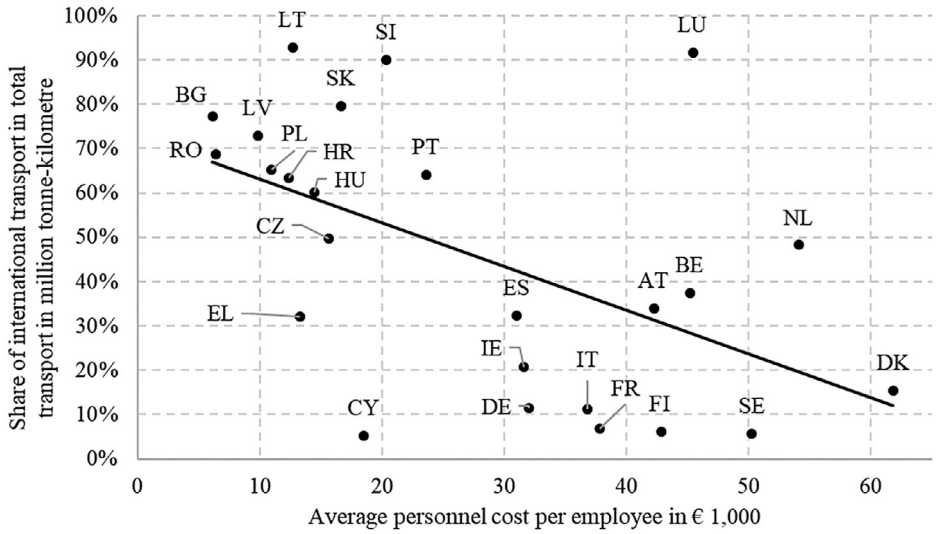
$$RCA_{i,t} = \frac{\left(\frac{RFT_{i,t}}{SRVC_{i,t}}\right)}{\left(\frac{RFT_{EU27,t}}{SRVC_{EU27,t}}\right)}$$

in which $RFT_{i,t}$ and $SRVC_{i,t}$ stand for road freight transport services (credit against the rest of the world) and export of services (credit) for country i in period t, while *EU*27 denotes 27 EU members.[6] An RCA index above 1 means that a country has a comparative advantage. The data show that the highest RCA levels in the sector are found in Lithuania (8.5), Latvia, the Czech Republic, Slovakia, Slovenia, Poland, and Romania among the CEE countries, as well as in North Macedonia and Bosnia and Herzegovina. The largest "old" EU-15 countries (Germany, France, and Italy) generally exhibit low or very low RCA indexes. Among the EU-15, only Austria—located between the "old" and "new" EU members—demonstrates a relatively high RCA. Notably, RCA levels remained relatively stable throughout the 2014–2022 period.

Thus, neither the average size of companies nor a country's level of technological advancement appear to correlate with the road freight sector's comparative advantage. Personnel costs[7] constitute a large share of operating costs in the European road freight sector, including salaries, wages, and social security payments. From 2011 to 2018, the share of personnel costs in total road freight service expenses ranged between 34% and 39% [**De Smedt, De Wispelaere, 2020**: 98].

The key components of personnel costs are wages and salaries paid per employee. In 2017, the annual average was EUR 21,536 per employee in the EU-28. The average cost exceeded EUR 35,000 in Sweden, Luxembourg, the Netherlands, and Denmark, while staying below EUR 8,000 in Bulgaria, Romania, Latvia, and Poland. It appears that personnel costs can correlate with the relative position of a given country's road transport sector. The next figure shows the relationship between personnel costs and the share of international transport.

Figure 1. Correlation between the average personnel cost per employee in EUR 1,000 and the share of international transport in total transport in million tonne-kilometre, 2020



Source: Authors' own calculations based on Eurostat data.

6 Belgium, Bulgaria, the Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden

7 Personnel cost is defined as the total remuneration, in cash or in kind, payable by an employer to an employee (regular and temporary employees as well as home workers) in return for work done by the latter during the reference period. Personnel costs also include taxes and employees' social security contributions retained by the unit as well as the employer's compulsory and voluntary social contributions.

The data show that countries with lower average personnel costs, primarily those in the CEE region, tend to trade (export) more, meaning they have a larger share of international transport in total transport services. Thus, we can expect that personnel costs, alongside other factors, influence the level of road transport service exports.

Data and methodology

In our study, we assume that the standard gravity variables are relevant for analysing the determinants of road transport services. Accordingly, we expect the GDP levels of exporting and importing countries, as well as the distance between them, to correlate with road freight service flows. We also assume that other standard gravity variables, such as the existence of a common border (contiguity) and a common language, should be positively associated with service flows. Finally, we treat the STRI index as quasi-equivalent to tariffs and goods, and we expect that they limit service flows between countries. We also expect the size and quality of the road network to correlate with a country's capability to provide these services.

Given the large share of personnel costs in the total costs of road freight transport and the observed correlations with exports, we expect relative personnel costs in the sector to impact its comparative advantage. We also draw on the presumption that larger companies—similar to those producing goods—benefit from economies of scale and are more efficient and export-oriented.

Precise definitions of the independent (explanatory) variables are provided in Table A2 in the Appendix. Summary statistics for the variables are presented in Table 2. The study relies primarily on data from the Eurostat database, complemented by additional sources (OECD and CEPII).

Table 2. Summary statistics for the variables used in the study

Variable	Source	Obs	Mean	Std.Dev.	Min	Max
Road freight transport (RFT)	Eurostat	2,914	69.257	192.76	0	3408.9
lnGDP_origin	Eurostat	2,914	11.836	1.3194	9.4761	15.061
lnGDP_destination	Eurostat	2,914	12.015	1.4852	9.2100	15.061
lnDistance	CEPII	2,914	11.501	0.6825	8.6125	12.817
Contiguity	CEPII	2,914	0.1112	0.3144	0	1
Comlang ethno	CEPII	2,914	0.0367	0.1881	0	1
Costs difference	Eurostat	2,914	2.5203	23.927	−55.3	55.3
Roads per area	Eurostat	2,914	0.4494	1.4066	0.0499	9.0650
Road tractors per firm	Eurostat	2,914	3.3670	1.6106	0.1257	6.9564
Business cycle origin	own calc.	2,914	−0.2488	0.5415	−2.0780	1.4166
Business cycle destination	own calc.	2,914	−0.2440	0.5541	−2.0780	1.7931
CEE	own calc.	2,914	0.5590	0.4966	0	1
STRI in RFT	OECD	1,926	0.1081	0.0316	0.0391	0.1750

Source: Authors' own calculations based on Eurostat data.

The dependent variable "road freight transport" was obtained from Eurostat's balance of payments statistics database, specifically the international trade in services tables. The data are available in a bilateral format, meaning they consist of exporter (origin/reporting) and importer (destination/partner) country pairs. Accordingly, we used credits for road freight transport services, measured in millions of euros at current prices.

The Gross Domestic Product series were drawn from Eurostat's National Accounts database and are expressed in millions of euros at current prices. Three variables from the French Center for Research and Expertise on the World Economy (CEPII) were used to quantify the distance between each pair of countries sharing borders and having the same language. As a measure of distance, we employed the population-weighted distance between the most populated cities (harmonic mean). The common-language dummy takes the value of 1 if at

least 9% of the population in both the origin and destination countries speaks the same language. The "roads per area" variable approximates the density of main roads. It was calculated as the ratio of the total length of motorways, expressways, and main roads to the total area of the country. The "road tractors per firm" variable approximates the average number of lorries and road tractors per firm, regardless of age or type. The CEE dummy variable indicates whether the exporter (origin country) is an EU member located in Central and Eastern Europe. We did not include an EU dummy variable because nearly all major countries analysed are EU members. To account for restrictions on transport services, we used the OECD's Services Trade Restrictiveness Index (STRI) for road freight transport.

To account for the state of the economy, we derived a business cycle indicator for each country using the Hamilton filter [**Hamilton, 2018**]. The cycle was extracted from quarterly, seasonally and calendar-adjusted GDP series at current prices. These quarterly indicators were then normalised and collapsed to yearly data using the mean function.

The Eurostat data on road freight transport services (our dependent variable) cover the period 2010–2022. However, the availability of average personnel costs only through 2020 narrowed the feasible time span. The baseline estimates were ultimately obtained for 2012–2019 due to missing observations for several control variables. In models with the STRI index, the data cover 2014–2019. Detailed definitions of all variables used in the study are provided in Table A2 in the Annex.

Since the data consisted of pairs of EU countries observed over multiple periods, the gravity trade model for road freight transport services was formulated as

$$\ln(rft_{i,j,t}) = X_{i,j,t}\beta + u_{i,j} + \varepsilon_{i,j,t}$$

in which the subscripts i, j, t run across exporters, importers and time periods respectively, the matrix $X_{i,j,t}$ contained control variables, while $u_{i,j}$ was an individual effect attributable to a specific pair of countries i and j. Since gravity trade models require log-transformed data and the road freight transport services variable contains a substantial number of zeros, applying a logarithmic transformation is not feasible. The commonly accepted solution in such cases is the Poisson Quasi-Maximum Likelihood (QML) estimator—also known as the Poisson Pseudo-Maximum Likelihood Method—advocated by **Santos Silva and Tenreyro** [**2006**]. The Poisson Quasi-Maximum Likelihood (PQML) method provides a framework for estimating models with continuous, non-negative dependent variables. Two essential elements of this framework are worth highlighting. The first is the logarithmic transformation of the dependent variable, as seen in log-linear or log-log linear regressions (e.g., structural gravity models). The second element is the identity of the conditional expected values of the dependent variable between the log-log (or log-linear) model and the Poisson regression. The advantage of the Poisson regression over the log-log (or log-linear) model lies in its ability to handle values where y=0. Further details of the Poisson Quasi-Maximum Likelihood method can be found in **Wooldridge** [**1997**] and **Wooldridge** [**2010**, ch. 18]. This approach, in the context of gravity trade models, relies on applying the Poisson regression to estimate parameters with a considerable number of zeros in the dependent variable. Although the Poisson regression is misspecified in the case of trade models, it provides consistent estimates of the parameters of a gravity trade model. Alternatively, the Tobit estimator [**Tobin, 1958**] can be applied. Moreover, **Yotov et al.** [**2016**] discussed further methods to estimate the parameters of gravity trade models. The advantage of the pooled Poisson estimator is its ability to estimate the parameters of time-invariant variables, which seems crucial from the gravity equation perspective.

Results

Table 3 presents the estimated models for the gravity equation for road freight transport services. Column (1) of Table 3 shows the baseline model, further extended with year dummy variables in Column (2). Columns (3) and (4) contain the counterparts to models from columns (1) and (2) augmented with the Service

Trade Restrictiveness Index (STRI). The STRI variable was unavailable for the entire set of countries in the sample, and therefore it considerably reduced the sample size for the models presented in Columns (3) and (4). Consequently, the models in Columns (1) and (2) were estimated using data for the period 2012–2019, whereas the models in Columns (3) and (4) were estimated on the shorter period 2014–2019.

Table 3. Estimated models for road freight transport services (RFT)

	Road freight transport (RFT)			
	(1)	(2)	(3)	(4)
lnGDP_origin	0.5268*** (0.0026)	0.5261*** (0.0027)	0.5238*** (0.0029)	0.5254*** (0.0029)
lnGDP_destination	0.7775*** (0.0021)	0.7778*** (0.0021)	0.8174*** (0.0027)	0.8196*** (0.0027)
lnDistance	−0.7236*** (0.0042)	−0.7145*** (0.0042)	−0.6748*** (0.0047)	−0.6661*** (0.0047)
Contiguity	0.2647*** (0.0071)	0.2821*** (0.0072)	0.3562*** (0.0080)	0.3725*** (0.0080)
Comlang ethno	0.2631*** (0.0080)	0.2577*** (0.0081)	0.2420*** (0.0092)	0.2396*** (0.0092)
Costs difference	0.0058*** (0.0002)	0.0061*** (0.0002)	0.0066*** (0.0002)	0.0063*** (0.0002)
Roads per area	0.0166* (0.0070)	0.0208** (0.0070)	0.5801*** (0.0225)	0.6036*** (0.0223)
Road tractors per firm	0.1105*** (0.0015)	0.1064*** (0.0015)	0.1177*** (0.0016)	0.1139*** (0.0016)
Business cycle origin	−0.1080*** (0.0054)	−0.2405*** (0.0067)	−0.1819*** (0.0061)	−0.3249*** (0.0075)
Business cycle destination	0.1382*** (0.0055)	0.0214** (0.0066)	0.0544*** (0.0068)	−0.0542*** (0.0079)
CEE	0.6443*** (0.0088)	0.6278*** (0.0088)	0.6970*** (0.0103)	0.7065*** (0.0103)
STRI in RFT			−3.4993*** (0.0954)	−3.3981*** (0.0948)
Year dummy variables	No	Yes	No	Yes
Constant	−4.9057***	−4.9687***	−5.6916***	−6.1605***
	(0.0580)	(0.0642)	(0.0643)	(0.0659)
chi2	402988.3	404940.9	312684.0	314258.7
p-value for the chi2	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.6865	0.6898	0.6777	0.6811
N	2914	2914	1926	1926
Log-likelihood	−92008.8343	−91032.5004	−74352.3290	−73564.9688

* p<0.05, ** p<0.01, *** p<0.001

Source: Authors' own elaboration.

The results support the validity of applying the gravity model to road freight transport services. Across all specifications, the estimates in columns (1)–(4) appear to be qualitatively identical. Our findings indicate that all standard gravity variables (exporter and importer GDP, distance, contiguity, and common language) align with our expectations and are consistent with the literature. With both GDP measures being positive and statistically significant, we observe the partner's GDP to correspond with the value of road freight transport (RFT) services.

To account for the economic conditions in both the exporter and importer economies, we included their respective business cycle indicators. We find a positive correlation between RFT exports and the performance of the destination economy. The opposite holds for the home country's business cycle. Our estimates suggest that long-term economic performance is negatively correlated with international road transport services:

when the home economy performs well, domestic demand for transportation services increases, reducing firms' incentives to engage in international transport activities. This negative domestic-cycle effect dominates the foreign-cycle effect in most specifications—columns (1)–(3), although the results in column (4) are somewhat contradictory.

In gravity trade models, distance typically proxies for transaction costs. In the case of road freight transport, distance represents the variable cost of each item (fuel, vehicle depreciation, etc.). As expected, our results show that greater distance reduces the value of transport service exports. This finding is highly robust, with the estimated elasticity ranging from 0.64 to 0.68.

For contiguity and common language, our results are in line with classical gravity literature. Sharing a border facilitates road freight transport services, supporting the idea that firms operate more easily in geographically and institutionally familiar markets where they incur lower marketing costs and are able to meet consumers' tastes. The positive and statistically significant estimate of the common language variable implies its positive correlation with RFT services. Although Europe is ethnically diverse, several major language groups—Romance, Germanic, Slavic, Uralic, Celtic, and Baltic—provide structural similarities that support business integration and cross-border service provision.

Another standard measure of trade barriers in gravity models is the Services Trade Restrictiveness Index (STRI). One of the biggest drawbacks of the index is its broad heterogeneity when used at the aggregate services level and its limited country coverage. To address these issues, we used the sector-specific STRI for road freight transport as an independent variable in specifications (3) and (4). Our findings indicate that greater regulatory restrictions reduce export values. This result is particularly relevant given the recent increase in institutional barriers for road transport firms. The role of STRI may increase because of new EU regulations on driver posting, minimum wages, and the maximum time for foreign operations.

A key contribution of this study is the attempt to include country infrastructure and assess the sources of comparative advantage in the export of freight road transport services. As shown in Table 3, higher road network density in a partner country is associated with a greater value of RFT services exported to this country. This result is intuitive and demonstrates that road infrastructure investment stimulates trade in goods, thereby increasing demand for international transport services. The effect is visible in models (2) and (3).

To capture economies of scale, we included the average number of road tractors per firm in the exporter country. The results show that firms with more trucks tend to export more, supporting the notion that larger companies can internalise certain costs and provide services more efficiently in foreign markets.

Finally, we examine the effect of personnel cost differentials between the destination country and the country of origin. Since personnel costs account for more than one-third of total operating expenses, this differential serves as a plausible proxy for comparative advantage. Our estimates show that larger cost differentials significantly increase RFT exports. This result is consistent and robust across all estimated models (1)–(4).

Conclusions

The RFT sector is the bloodstream of the European economy. However, no comprehensive econometric analysis has yet explained the geographic structure of these services among European countries. In this paper, we analyse the value of bilateral RFT services using a structural gravity model. We demonstrate that the gravity model—widely used in the analysis of merchandise trade—can also be applied to trade in RFT services. We extend the model's explanatory variables to account for the specific features of the European RFT sector. Our analysis focuses on CEE countries, examining their role in RFT services after EU accession.

We employ Poisson regressions to estimate the explanatory variables of the gravity model. Our results show that the signs of all standard gravity variables (GDP of trading partners, distance, contiguity, and common language) are consistent with the literature on merchandise trade flows. Both GDP measures are positive and statistically significant. The contiguity and common language variables also exhibit positive signs.

We use two variables to proxy transportation costs between countries. The first is distance; the estimator of this variable reveals a negative sign in line with gravity model studies. We also include a roads-per-area variable to capture the impact of road network density, which changed substantially over the analysed period, particularly in CEE countries. The positive sign of this variable confirms that better road infrastructure is associated with greater RFT service expansion.

We further extend the standard gravity model by including variables representing business cycle fluctuations in both the origin and destination countries. We observed a positive relationship between the value of services exports and the business cycle in the destination economy, consistent with expectations. In contrast, we found a negative correlation between exports and the business cycle of the exporter economy. This result requires further analysis. We hypothesise that an upswing in the home country's business cycle boosts domestic demand for transportation services and reduces demand for RFT exports while controlling for total GDP.

Our results also highlight the large share of CEE countries in RFT services. The estimator for the CEE dummy variable is statistically significant and positive, indicating that these countries have a "comparative advantage" in the RFT sector. This probably reflects the benefits of EU accession (and net transfers from EU structural funds used to modernise road infrastructure), the expansion of East-West trade flows, the growing involvement of CEE economies in GVCs, lower wage levels, and rapidly rising domestic and foreign demand.

We extend the estimations by adding RFT sector-specific variables. To capture internal economies of scale, we include the number of road tractors per firm in the exporting country. The positive sign of the estimator confirms that economies of scale matter and that larger firms are more competitive. Another variable reflects differences in personnel costs between countries, capturing relative RFT cost structures—particularly important given that personnel costs account for more than one-third of total costs in the sector. The positive sign of this variable confirms that lower personnel costs improve a country's competitive position (based mostly on the relative wage component) in RFT services. We hypothesise that this factor is especially important in the case of CEE countries.

The last explanatory variable is the Services Trade Restrictiveness Index (STRI), which captures sectoral trade barriers. Our estimates indicate—in line with expectations—that higher STRI values are associated with greater restrictions and lower export values.

Several limitations apply to our analysis. The model was estimated only up to 2019 due to limited availability of explanatory variables. Since then, the RFT sector has faced—and will continue to face—many challenges. The COVID-19 pandemic slowed economic activity and sharply reduced international trade. The Russian invasion of Ukraine disrupted East-West trade flows, while the recent economic slowdown in Germany—one of Europe's largest trading economies—further reduced demand for various RFT services.

Other challenges arise from evolving EU policies. Climate policy measures requiring reductions in CO_2 emissions will increase future operating costs for hauliers. New EU regulations on posting drivers and minimum wages are raising personnel costs, particularly for CEE firms whose competitive advantage historically rested on low labour costs. Decreasing inflows of Ukrainian drivers and rising minimum wages in some CEE countries will further weaken the strong competitive position of their RFT sectors. Combined with an ageing driver workforce, these developments may significantly erode some countries' trade advantages.

In this context, several policy recommendations follow. There is a real risk that the STRI index will gradually increase, reducing the internationalisation of the European RFT sector. Specialists in the field should analyse in detail the main components of the STRI index— (i) regulatory transparency, (ii) barriers to competition, (iii) other discriminatory measures, (iv) restrictions on the movement of people, and (v) restrictions on foreign entry—to identify which barriers most significantly reduce RFT service volumes. Some of these could be eased. For example, all RFT firms must apply for documents from the International Road Transport Union (TIR). These procedures can be costly and burdensome, especially for the small firms that dominate the Polish market. Governmental websites and other instruments could simplify this process. Current regulations also require the installation of new tachographs to improve monitoring of drivers' working time

and reduce infringements. Preferential credit schemes for small Polish RFT companies operating locally and in the EU could also be considered.

Finally, the government could increase pressure on EU partners to slow the implementation of stringent environmental requirements for trucks. The Emissions Trading System 2 (ETS2), scheduled to become fully operational in 2027, will cover CO_2 emissions from fuel combustion in RFT and other sectors. Fuel suppliers will need to monitor and report their emissions and purchase allowances at auctions, which will increase the cost of fuel. Meanwhile, the Euro 7 standards proposed in November 2022 would introduce more stringent pollutant emission limits for combustion-engine vehicles, including trucks and other heavy-duty vehicles. A slower implementation of Euro 7 may be necessary to preserve the competitiveness of the European RFT sector, particularly given shifts in US energy policy following Washington's withdrawal from the Paris Agreement.

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Appendix

Table A1. International road freight transport—loaded goods in reporting country by country of unloading, type of goods and type of transport (t) in thousand tonnes

Country	2014	2016	2018	2020	2022
Belgium	17 279	18 991	19 159	18 189	18 123
Bulgaria	3 920	5 532	4 501	5 248	6 531
Czechia	19 972	17 488	12 708	14 858	18 172
Denmark	2 001	1 661	1 399	1 132	1 135
Germany	45 555	45 730	42 783	36 505	36 111
Estonia	1 439	1 668	1 135	1 001	1 021
Ireland	1 960	2 326	2 251	1 922	1 854
Greece	1 263	1 401	3 915	2 082	1 621
Spain	25 929	28 422	32 081	30 607	36 709
France	22 309	16 994	19 137	17 241	20 296
Croatia	3 926	4 892	5 037	4 993	5 271
Italy	9 804	7 634	8 867	9 211	11 684
Cyprus	11	14	18	11	27
Latvia	2 754	2 716	3 387	3 072	3 520
Lithuania	4 454	4 466	5 106	5 213	4 643
Luxembourg	6 527	6 351	5 550	5 609	6 037
Hungary	11 071	13 890	16 337	14 156	17 428
Netherlands	49 775	46 688	47 892	46 964	42 300
Austria	10 176	10 739	10 345	9 508	10 295
Poland	55 220	63 573	68 071	74 270	79 880
Portugal	9 248	8 973	8 990	5 978	7 871
Romania	4 705	5 733	7 235	6 123	7 932
Slovenia	6 651	6 949	8 041	8 691	9 595
Slovakia	9 215	11 474	12 461	10 149	10 891
Finland	2 370	1 445	1 448	1 201	772
Sweden	2 264	2 588	2 009	1 958	1 470
Norway	1 793	1 705	1 785	1 665	1 763
Switzerland	6 270	4 692	4 894	5 774	7 322
United Kingdom	7 653	6 348	6 847		

Source: Eurostat: International road freight transport—unloaded goods in reporting country by country of loading, type of goods and type of transport [road_go_ia_ugtt].

Table A2. Detailed information on the variables used in the study

Variable	Description	Source
Road freight transport	The dependent variable measures road freight transport services [SC3C2], Credit [CRE]. Annual data from the Eurostat database. The variable was measured in million euros.	Eurostat: [bop_its6_det]
lnGDP origin	The logarithm of gross domestic product at market prices [B1GQ] is measured in million euro [CP_MEUR] of the country reporting credit in road freight transport services. Annual data was downloaded from the Eurostat database. The variable was neither seasonally nor calendar adjusted.	Eurostat: [nama_10_gdp]
lnGDP destination	The logarithm of gross domestic product at market prices [B1GQ] is measured in million euro [CP_MEUR] of the destination country of road freight transport services. Annual data was downloaded from the Eurostat database. The variable was neither seasonally nor calendar adjusted.	Eurostat: [nama_10_gdp]
lnDistance	The logarithm of the population-weighted distance between the most populated cities (harmonic mean).	CEPII
Contiguity	The dummy variable takes on 1 as a value if the origin and destination countries are contiguous.	CEPII
Comlang ethno	The dummy variable takes on 1 as a value if the same language is spoken by at least 9% of the population in the origin and destination countries.	CEPII
Costs difference	The difference in average personnel costs (personnel costs per employee) was calculated as the difference between the costs in the destination and origin countries. The variable is measured in thousand euros [V91210] and considered economic activities under freight transport by road classification [NACE_R2 = H4941]. The data was downloaded from the annual detailed enterprise statistics for services. Positive values of the variable indicate higher costs in the destination country than in the origin country.	Eurostat: [sbs_na_1a_se_r2]
Roads per area	The variable was calculated as a sum of the length in kilometres of all motorways, expressways and country roads in the destination country divided by the country's total area. Missing observations in the components of the sum were interpolated.	Eurostat: [road_if_motorwa], [road_if_roadsc], [reg_area3]
Road tractors per firm	The variable was a ratio of two indicators. The numerator was the total number of lorries and road tractors regardless of their age and type. The denominator was the total number of companies classified under the NACE R2 H4941 classification as road freight transport companies.	Eurostat: [road_eqs_lorroa], [sbs_na_1a_se_r2]
Business cycle origin & Business cycle destination	The variables quantify the business cycle in the origin and destination countries. The variable was calculated using the Hamilton filter (Hamilton, 2018) for quarterly GDP data. The underlying GDP indicator was at current prices, million euro [CP_MEUR], seasonally and calendar adjusted data [SCA]. To appropriately derive the business cycle indicators, we used as many observations as possible and available in the Eurostat database (maximal data span covered the end of period 1975Q1-2023Q4). The derived quarterly business cycle indicator was collapsed to yearly observation using the mean function. Positive values indicate the economy's condition surpasses the potential product, while negative values indicate the economy's condition falls behind the potential product.	Own calculations based on Eurostat: [namq_10_gdp]
CEE	The dummy variable takes on 1 as a value for countries: Bulgaria, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia and Slovakia.	Own calculations.
STRI in RFT	The service trade restrictiveness index in road freight transport. The variable is limited to [0; 1] interval. The higher the values, the more restrictions in the country were imposed.	OECD

Source: Authors' own elaboration.

Table A3. Correlations between independent variables used in the analysis

Variable	lnGDP_origin	lnGDP_destination	lnDistance	Contiguity	Comlang ethno	Costs difference	Roads per area	Roadtractors per firm	Business cycle origin	Business cycle destination	CEE	STRI in RFT
lnGDP_origin	1.00											
lnGDP_destination	−0.02	1.00										
lnDistance	0.00	0.00	1.00									
Contiguity	0.02	0.02	−0.58	1.00								
Comlang ethno	−0.03	−0.03	−0.33	0.46	1.00							
Costs difference	−0.36	0.36	0.00	0.00	0.00	1.00						
Roads per area	0.01	−0.32	0.09	−0.06	0.01	−0.06	1.00					
Road tractors per firm	0.08	0.00	−0.02	0.02	0.01	−0.07	0.00	1.00				
Business cycle origin	0.08	0.04	0.02	−0.01	0.00	−0.02	−0.03	−0.02	1.00			
Business cycle destination	0.04	0.08	0.02	−0.01	0.00	0.02	0.02	0.01	0.58	1.00		
CEE	−0.17	0.00	−0.15	0.03	−0.05	0.53	0.00	−0.10	−0.09	0.00	1.00	
STRI in RFT	0.00	0.14	0.25	−0.04	0.03	0.31	−0.36	0.00	0.00	−0.07	0.01	1.00

Source: Authors' own elaboration.