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Assessing the Effects of Logistics Performance on Energy Trade

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Abstract: Logistics has become one of the most important economic sectors. It significantly affects the transport infrastructure and many other sectors that are crucial for the country's development. It is the factor that also influences trade efficiency. However, the question arises if logistics performance is significant for the trade of critical goods which are energy raw products. The aim of the paper is primarily to investigate the EU energy trade flows in general and to estimate the effect of logistics performance on the international trade of energy raw products. The energy raw products are grouped into solid, liquid, and gaseous products, and separate estimates are made for their export and import. The analysis also differentiates between the trade flows, that is export and import within the EU and trade flows between EU member states and third countries. The empirical model is based on the theory of gravity model extended to include the six subcomponents of the Logistics Performance Index (LPI). The results present that: (1) the standard gravity model variables, such as GDPs of reporter and partner countries and contiguity, are successful in explaining the trade flows of solid and liquid raw energy but in case of gas products, are insignificant; (2) the results indicate that all logistics' performance subcomponents are highly significant and show positive effects on the export of liquid energy products, while for the solid and gas products, it seems to be insignificant when the energy commodities are more complex and costly to transport and store, and therefore, contiguity, i.e., when countries share a common border, positively affects energy trade; (3) the EU imports most liquid energy products, but is generally very dependent on energy imports. EU policymakers should strive to either make more use of domestic resources or switch more to renewable energy sources.

Keywords: logistics performance; energy trade; gravity model; GDP; export; import

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1. Introduction

Logistics has become one of the most important economic sectors. It significantly affects the transport infrastructure and many other sectors that are crucial for the countries and regions' development. On a micro-scale, it meaningfully increases the attractiveness of corporations, while on a macro scale, it has a major contribution to the national economy, creating employment, national income, and affecting foreign investment and trade. In the past, several scholars have used different models and methods to study the importance of logistics on economic development, the environment, and energy consumption. Their research results present that the expansion of effective logistics activities and businesses has an impact on breaking down the barriers between regions and linking raw materials and sub-products suppliers, production, and final consumers [1]. Most academics underline that logistics performance and economic growth are interconnected in a way that the development of the logistics industry constantly promotes regional development and builds economic integration [2–7].

In order to score the overall level of logistics services provided in a specific country, the benchmarking tool Logistics Performance Index (LPI), was introduced by the World

Bank. It consists of six sub-dimensions which are said to be the most important groups of indicators influencing the logistics state in region on country. Those are as follows:

- The good organization of customs clearance processes, such as speed, simplicity, and predictability;
- The excellence of transport infrastructure: ports, railroads, roads, and information and communication technology, etc.;
- The simplicity and affordability of handling shipments inside and outside the infrastructure;
- The competence in the local logistics services industry, which measures the competence and quality of logistics service providers, such as transport operators and customs brokers;
- The ability to track shipments throughout the logistics chain;
- The regularity of when the deliveries reach the consignee within the scheduled or expected time.

By scoring the overall logistics condition and representing the average of the six sub-dimensions of logistics performance, LPI measures the country's connections to international logistics networks. It gives a reasonable understanding of achievements in logistics at the national level for several countries around the world. The LPI rank gives comprehensive knowledge and feedback on the logistics accessibility of the countries in which the operators run business and with which they trade [8].

Since the introduction of the logistics performance index, it has been widely used in many trade-oriented research studies and has been used as a proxy variable for trade facilitation. However, these studies usually focused on total trade or trade in consumer goods, while certain groups of commodities, such as energy products, were not considered in the analyses. The aim of this paper is therefore to examine whether the trade flows of energy differences between the EU Member States and between the EU and third countries and how these regional trade paths affect energy trade. Furthermore, this research aims to investigate the role of logistics in the trade of energy products, focusing on the 28 EU Member States. This topic is relevant from a macroeconomic point of view, as energy plays an important role in the development of any country or region and is important in the creation of further development policies, especially in the European Union. From a microeconomic point of view, the cost of energy products affects the general operating costs and the competitiveness of enterprises. Therefore, it is important to facilitate trade in energy products. To the best of our knowledge, there are no prior studies that put the specify of raw energy products trade, size of economy, and logistics performance indices together. The main novelty of this paper is that we use an established gravity model to test the effects of the components of logistics performance on energy commodity trade and to find out which type of energy commodity is more responsive to the improvement in a particular component of logistics performance. Before going into the deep analysis of the influence of LPI and GDP on energy raw products trade, it is crucial to present the global trends of the demand (consumption) for energy. Investigating this issue, it is visible that currently, it is fluctuating. In several parts of the World, e.g., western European countries, there is a strong trend to switch energy production using renewable energy sources, however, on a worldwide scale, fossil fuels: coal, oil, and gas, still play a leading role in global energy systems [9] representing approximately 82% of the global energy supply (Figure 1).

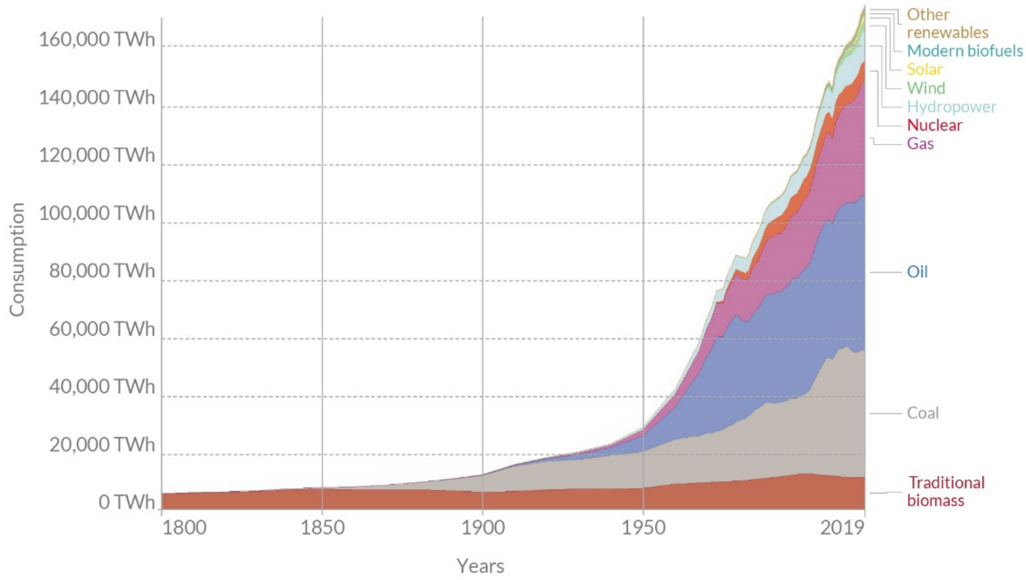
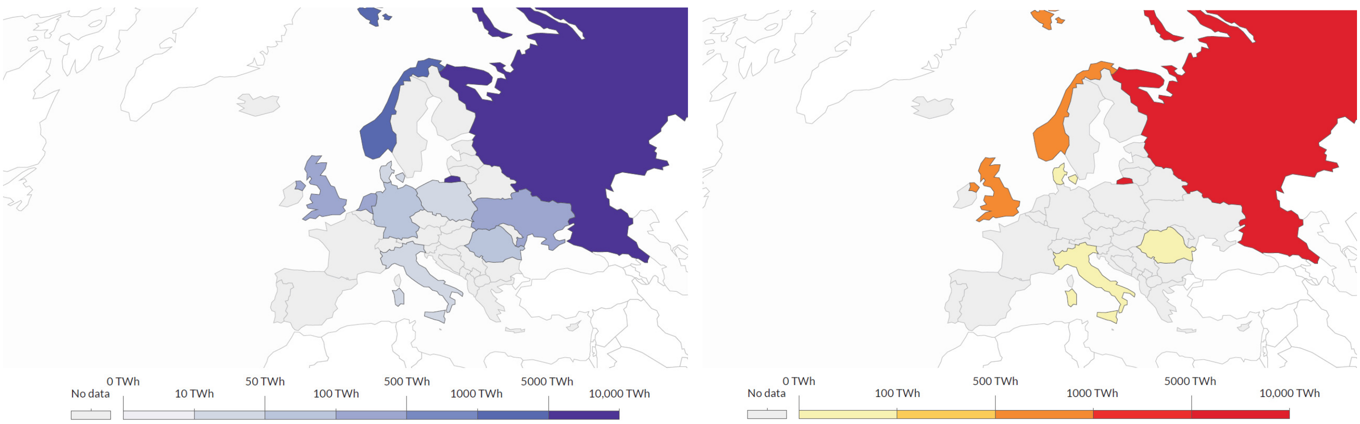


Figure 1. Global primary energy consumption by source in 1800–2019. Source: [10].

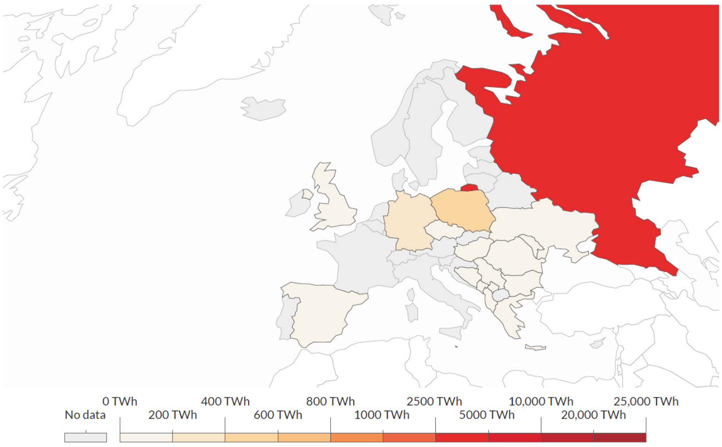
According to the World Bank data, the US is the biggest producer of fossil fuels and reached 20% of the world's global fossil fuels production. It is followed by Russia, Iran, and Canada.

In Europe, the production of fossil fuels is limited and diversified in terms of products (Figure 2). Natural gas production in 2019 amounted to 101 billion m^3 (the UK the leader) (Figure 2a), the production of oil—1.5 million barrels per day (the UK the leader) (Figure 2b). At the same time, Poland was the leader in coal production, which amounted overall to 56.5 megatons (Figure 2c).



(**a**) (**b**)

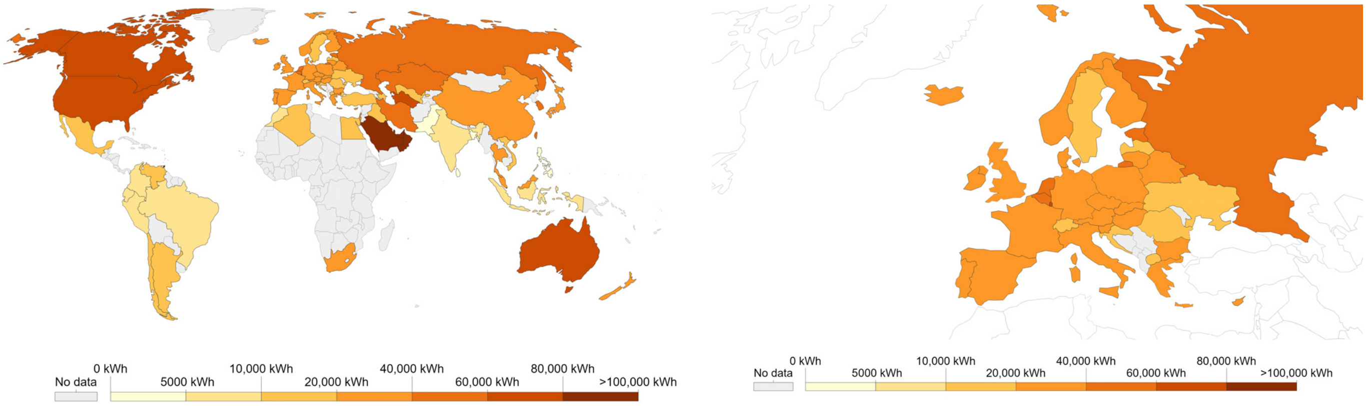
Figure 2. *Cont.*



(**c**)

Figure 2. European gas (**a**), oil (**b**), and coal (**c**) production in 2019. Source: [10].

The average consumption of energy from coal, oil, and gas per capita presents large spatial differences (Figure 3a). Similarly, in Europe, it is Russia and Lithuania followed by Germany (Figure 3b).



(**a**) (**b**)

Figure 3. Global (**a**) and European (**b**) fossil fuel consumption per capita in 2019. Source: [10].

This paper consists of five parts. After the introduction, the second part, the literature review, presents the existing literature on the relationship between logistics performance and trade in different products and between different countries. The third part presents the methodology and the description of the variables used in the analysis. The fourth part presents the estimation results and discussion of the estimates, while the fifth part, the Conclusion, provides concluding remarks and suggests directions for further research.

2. Literature Review

The importance of logistics in economics has meant that for the last two decades, the logistics performance score has been used numerously by researchers and data analytics for measuring the importance of logistics for several economic sectors, including international trade. There are examples of investigation results on this topic (Table 1).

Table 1. Research on logistics performance and trade—a literature review.

Authors	Trade	Research Areas	Model/Estimator	Findings
Zaninović et al. [11]	international bilateral trade	UE-28 and its 129 trading countries	Structural gravity model, Poisson pseudo-maximum probability estimator LPI sub-groups	✓ differences in LPI values have a heterogeneous impact on bilateral trade, especially trade in different classes of goods and different groups of country pairs.
Kaplan and Bozyiğit [12]	foreign trade	Turkey and its 26 trade countries	Regression model	✓ LPI has a positive effect on foreign trade except for service quality.
Jouili and Khemissi [13]	seaborne trade	Tunisia	Comparison analysis LPI sub-groups and Seaborne trade	✓ LPI and its six sub-dimensions are statistically significantly correlated with seaborne trade
Zhan and Wang [14]	foreign trade	Sichuan Province	VAR model	✓ long-term between total import and export volume, total transport volume, and logistics network mileage
Çelebi [15]	international trade	low-, medium- and high-income economies	Gravity model	✓ low- and lower-middle-income economies, logistics excellence increases exports more than imports, ✓ imports of upper-middle- and high-income economies benefit from better LPI than their exports, ✓ improving LPI of partner countries leads to a higher impact on the exports of an upper-middle-income country than improving only the exporter's performance.
Katrakylidis and Madas [16]	39 worldwide countries		Panel unit root tests, pooled mean group (PMG) models, Granger-causality analysis	✓ Indirect effect (through economic growth) of logistics sector for international trade
Wang et al. [17]	international trade	developing countries	Augmented gravity model with semi-economic and political variables Logistics CO_2 intensity, Environmental logistics performance index	✓ LPI of exporting and importing countries positively correlates with trade volume.
Gani [18]	international trade	60 countries	Cross-sectional estimation, time-series data 6 LPI sub-groups	✓ LPI significantly and positively affects mostly export.
Bensassi et al. [19]	international trade	19 Spanish regions to 64 destinations	Augmented gravity model including logistics and transport infrastructure indicators	✓ LPI is important for trade flows of goods, in terms of number, size, and quality of logistics facilities.

Table 1. *Cont.*

Authors	Trade	Research Areas	Model/Estimator	Findings
Martí et al. [20]	international trade	Africa, South America, Far East, Middle East, and Eastern Europe	Gravity model LPI sub-groups	✓ LPI sub-dimensions cause an increase in trade, ✓ LPI is important for Africa, South America, and Eastern Europe.
Puertas et al. [21]	international and domestic trade	Europe	Gravity models with the two-stage Heckman model LPI sub-groups	✓ LPI has the greatest impact on international trade, ✓ competence and tracking with greater importance in the past
Hausman et al. [22]	international trade	80 countries	Gravity model 3 sub-groups of LPI: time, cost, and reliability	✓ LPI is significantly related to the volume of bilateral trade.
Xun and Fuhua [23]	international and domestic trade	China	VAR model VEC model	✓ a unique co-integration relationship among the logistics industry, domestic trade, and foreign trade, ✓ the logistics industry's role in promoting foreign trade and domestic trade is stable, ✓ domestic trade plays a more significant role in logistics than foreign trade.
Hoekman and Nicita [24]	international trade	low-income countries	Cross-section gravity model distance, adjacency, common language, access to the sea and trade policy variables	✓ tariff and non-tariff barriers are obstacles to international trade, ✓ LPI improvement promotes the development of international trade in developing countries, ✓ behind-the-border measures of LPI are important to improve the effectiveness in expanding developing country trade, especially exports.
Nguyen and Tongzon [25]	bilateral trade	Australia–China Australia–Japan Australia–US	VAR model	✓ no direct linkages between logistics infrastructure development and international trade, ✓ the development of international trade promotes the construction of domestic logistics infrastructure.

Conforming to the above-mentioned results, it can be claimed that the related research on the relationship between logistics performance and domestic or international trade has gained positive outcomes.

Much more difficult is when searching for the results on the influence of energy on bilateral trade. Narayna and Nguyen [26] concluded their research by showing that bilateral exports are more responsive for clean (hydrogen) than dirty (fossil) generated electricity between world regions. However, there are research gaps that we noticed. For example, the literature typically focuses on the trade analysis (import–export) as a global phenomenon, without the differentiation on the specific goods. This research differs from previous studies in that it adopts only the group of fossil fuels products and within the EU and differentiated between the EU and the rest of the world approach. Fossil fuels are extremely important for logistics operations. Simultaneously transport networks and storage facilities dedicated to fossil fuel flow are capacity intensive and complex [27].

From the literature analyzed, there is a lack of evidence on the impact of logistics performance on energy products trade. Although it is well known in the literature that the EU is generally dependent on foreign energy, the empirical literature fails to quantify precisely how intra-EU energy trade flows differ in value compared to energy trade between the EU and third countries. The hypothesis is as follow: It is expected that logistics performance in relation to the standard gravity variables, such as gross domestic product and proximity between countries, has a positive impact on energy trade flows, however different types of energy products and different trade paths bear a different degree of relevance for trade.

3. Methodology

3.1. Research Methods

This paper used a panel data regression analysis based on the theory of the gravity model of international trade. The gravity model is one of the most empirically successful models in economics [28] and is considered the workhorse of the applied international trade literature [29]. The idea behind the gravity model of international trade comes from physics, i.e., Newton's universal law of gravity, which started with the work of Jan Tinbergen in 1962 [30].

The gravity model describes bilateral aggregate trade flows between two countries (trading partners) as proportional to their economic mass, measured by gross domestic product, and inversely proportional to the distance between them, measured by the air distance between the capitals of the two countries [31]. The canonical gravity model has the following form:

$$logX_{ij} = \alpha + log\beta_1 gdp_i + \beta_2 loggdp_j + \beta_3 logdist_{ij} + u_{ij} \quad (1)$$

where X_{ij} stands for exports from country i (reporting country) to country j (partner country), gdp_i and gdp_j represent reporting and partner countries gross domestic products. $dist_{ij}$ stands for the geographical distance between reporting and partner countries which serves as a proxy variable for trade costs. u_{ij} is an error term, α is regression constant, and $\beta_1, \beta_2,$ and β_3 are parameters. The gravity equation states that trading partners with a larger GDP can be expected to trade more and countries that are farther apart can be expected to trade less due to higher transportation costs [32].

However, in the majority of empirical studies, the gravity model usually incorporates other socio-economic variables, such as common language, border, currency, or colonial history, between trading partners. Since the first report on the logistics performance index in 2007, published by the World Bank, many authors interested in trade logistics and trade facilitation have started to include the logistics performance index in their gravity model [11,20,33–35].

This analysis estimates the impact of logistics performance, measured by six sub-components of the logistics performance index, on bilateral trade in energy between the

EU Member States and their trading partners (including the EU Member States and third countries).

Two structural gravity models were estimated, the first in the case of exports and the second in the case of imports. The gravity equation has the following structure:

$$eng\_export_{ijt} = \beta_0 + \beta_1 gdp_{it} + \beta_2 gdp_{jt} + \beta_3 dist_{ij} + \beta_4 contig_{ij} + \beta_5 lpi\_comp_{it} + \beta_6 group_{ijt} + \lambda_t + u_{ijt} \quad (2)$$

$$eng\_import_{ijt} = \beta_0 + \beta_1 gdp_{it} + \beta_2 gdp_{jt} + \beta_3 dist_{ij} + \beta_4 contig_{ij} + \beta_5 lpi\_comp_{it} + \beta_6 group_{ijt} + \lambda_t + u_{ijt} \quad (3)$$

wherein Equation (2) eng_export_{ijt} is the value of export between reporting country i and partner country j in year t expressed in US dollars, and in Equation (3) eng_import_{ijt} is the value of import between reporting country i and partner country j in year t expressed in US dollars. In this case, t represents the years 2010, 2012, 2014, 2016, and 2018 because the logistics performance index is published every two years, so the estimations of the model were performed only for these years. The focus of the analysis was mainly on the EU member states, therefore, as reporting countries, i in the dataset was 28 EU member states. As partner countries j, 157 countries were included in the dataset, including 28 EU member states and other non-EU countries. For 2010 and 2012, the sample includes 152 partner countries because five countries were not included in the LPI report in these years. β_0 is a regression constant, while $\beta_1 - \beta_6$ are parameters of the independent variables.

As the proxy variable for economic size was used to report country's gross domestic product gdp_{it}, and the partner country's gross domestic product gdp_{jt}. The geographical distance between trading partners, namely their capital cities is $dist_{ij}$. $contig_{ij}$ is the presence of a common border, that is, it is a dummy variable that has a value of one if the trading partners share a common border or a value of zero if they do not share a common border. $comlang_{ij}$ represents the presence of a common language between trading partners. It is a dummy variable with a value of one if the trading partners have a common official language and a value of zero if they do not have a common official language. lpi_comp_{it} stands for the six subcomponents of logistics performance. The six LPI subcomponents are as follows [8]: the efficiency of the clearance process (Customs), the quality of trade and transport infrastructure (Infrastructure), the ease of arranging competitively priced shipments (International), the competence and quality of logistics services (Logistics), the ability to track and trace consignments (Tracking), and the timeliness of shipments with expected delivery time (Timeliness). The models were estimated (2 and 3) separately for each subcomponent of the LPI because there is a high degree of correlation between them. Since we were interested in the impact of logistics performance in the case of EU Member States, we included in the estimation only the LPI subcomponents of the reporting countries, i.e., the 28 EU Member States. $\beta_7 group_{ijt}$ is a dummy variable which has the value 1 if the trade flows (export or import) take place within EU countries, or it has the value 0 if the trade flows (export or import) take place between EU countries and third countries (ROW-rest of the world). The "group" dummy variable was included to control for the trade flows between partners/regions. Term λ_t represents time fixed effects, while u_{ijt} stands for the error term. Following the seminal work of [28], fixed effects were included in the estimation to account for the correlation of error terms within country pairs, and we included country-pair clusters in the estimates.

The estimation of the models was performed with the (2 and 3) Poisson Pseudo-Maximum Likelihood Estimator (PPML), originally introduced by [36] for gravity models. PPML is often used as an estimator in trade-related estimations [10,37,38] because it solves the problem of zero values in trade between trading partners by allowing zeros, thus avoiding the potential bias in research results. The dataset consisted of 11.96% observations at the country pair level with zero exports and 41% observations at the country pair level with zero imports.

3.2. Data and Variables

The dataset contained data for 157 countries in the years 2010, 2012, 2014, 2016, and 2018. As a dependent variable, trade data was used, namely separately export and import data of energy raw materials, following the HS 2017 classification, code 27 "Mineral fuels, mineral oils, and products of their distillation; bituminous substances; mineral waxes", 4-digit heading (2701–2715). The energy products were grouped into three groups: solid products, liquid products, and gas products (Table A1).

Table 2 provides the description of the variables, measures, and sources.

Table 2. Description of variables and sources.

Variable	Indicator	Description	Source
Dependent variable(s)	*eng_export* (export) *eng_import* (import)	The absolute values of export and import in US dollars	UN Comtrade database
Independent variables	*gdp* (Gross domestic product)	The natural logarithm of gross domestic product	World Bank Open Data
	dist (distance)	Geographical distance between capital cities of reporting country *i* and partner country *j* in kilometers	CEPII
	contig (contiguity)	Dummy variable with value 1 in the case when reporting country *i* and partner country *j* share a common border, and with value 0 if they do not	CEPII
	lpi_comp (Logistics Performance Index)	The Logistics Performance Index (LPI) is compiled based on a global survey of more than 5000 international freight forwarding and logistics companies. Each respondent rates their trade logistics experience (in six components, i.e., customs, infrastructure, international, logistics, tracking, timeliness) in the eight countries with which they trade the most. Based on their responses, LPI sub-components are constructed using principal component analysis (PCA). The indices can take values between zero and five, with zero being the worst and five being the best. For a detailed explanation of how the indices are constructed, see the Connecting to Compete Report [8].	World Bank, Connecting to Compete Reports (2010–2018)
	group	Dummy variable which has the value 1 if the trade flows (export or import) take place within EU countries, or it has the value 0 if the trade flows (export or import) take place between EU countries and third countries (ROW-rest of the world).	CEPII

Source: Authors' elaboration.

Table 3 presents descriptive statistics for the variables included in the models (2 and 3).

Table 3. Descriptive statistics.

Variable	Observation	Mean	Standard Deviation	Minimum	Median	Maximum
eng_import	21,787	1.55×10^8	1.13×10^9	0	2625	4.36×10^{10}
eng_export	21,787	6.38×10^7	5.32×10^8	0	145,862	3.08×10^{10}
gdp_i	21,787	8.73×10^{11}	1.08×10^{12}	8.75×10^9	3.82×10^{11}	3.95×10^{12}
gdp_j	21,572	8.64×10^{11}	2.42×10^{12}	2.53×10^8	1.88×10^{11}	2.05×10^{13}
$dist$	21,787	4461.87	3707.106	160.9283	3210.535	19,539.48
$contig$	21,787	0.05	0.221	0	0	1
$comlang$						
lpi_comp (customs)	21,787	3.42	0.448	2.36	3.47	4.12
lpi_comp (infrastructure)	21,787	3.58	0.540	2.25	3.72	4.44
lpi_comp (international)	21,787	3.45	0.331	2.69	3.51	4.24
lpi_comp (logistics)	21,787	3.59	0.464	2.53	3.71	4.31
lpi_comp (tracking)	21,787	3.67	0.440	2.54	3.82	4.38
lpi_comp (timeliness)	21,787	3.99	0.374	2.88	4.06	4.8

Source: Authors' calculation.

Descriptive statistics showed that for the dependent variables import and export, the standard deviation was significantly higher for exports than for imports. For the GDPs of the reporting and partner countries, the standard deviation was also higher in the case of the partner countries, because in the dataset there were 28 reporting countries (28 EU member states), and 157 partner countries at different levels of economic development.

As for the logistics performance variables, the descriptive statistics showed the subcomponents of logistics performance only for the reporting countries, i.e., the 28 EU Member States. If one observes the mean values, it can be seen that all subcomponents of logistics performance were close in score. However, in the Descriptive Statistics column, it was noticeable that the differences between the EU Member States were larger for the quality of infrastructure, while the smallest standard deviation was recorded for the variable International, which stands for the ease of arranging shipments at competitive prices. Since pricing is mainly in the hands of private companies, most of which operate throughout the EU, it is understandable why the standard deviation is the smallest in this case. On the other hand, differences in the quality of infrastructure, especially between the old and new EU Member States, are a long-standing problem that should be improved.

Table 4 presents descriptive statistics for the trade flows of energy products within the EU (when one EU member state exports or imports in another EU member state) and between EU member states and third countries, which are not EU members. Third countries are labeled as ROW (rest of the world).

Table 4. Descriptive statistics of the energy trade between two groups of countries EU28-EU28 and EU-ROW.

Group	Trade Flow	Observation	Mean	Standard Deviation	Minimum	Maximum
EU-EU	export	2986	10,751,887	57,784,968	0	1.28×10^9
EU-EU	import	2986	9,910,905	50,684,146	0	1.26×10^9
EU-ROW	export	4955	1,294,274	8,078,235	0	2.51×10^8
EU-ROW	import	4955	20,455,249	1.1×10^8	0	2.09×10^9
Total solid	export	7941	4,850,556	36,290,815	0	1.28×10^9
Total solid	import	7941	16,490,331	92,570,226	0	2.09×10^9

Table 4. *Cont.*

Group	Trade Flow	Observation	Mean	Standard Deviation	Minimum	Maximum
EU-EU	export	3529	2.55×10^8	1.23×10^9	0	3.08×10^{10}
EU-EU	import	3529	2.92×10^8	1.72×10^9	0	4.36×10^{10}
EU-ROW	export	9856	46,007,173	2.65×10^8	0	9.17×10^9
EU-ROW	import	9856	2.24×10^8	1.31×10^9	0	3.22×10^{10}
Total liquid	export	13,385	1.01×10^8	6.76×10^8	0	3.08×10^{10}
Total liquid	import	13,385	2.42×10^8	1.43×10^9	0	4.36×10^{10}
Group	**Trade Flow**	**Observation**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
EU-EU	export	301	4172.867	43,440.04	0	742,721
EU-EU	import	301	98,966.79	676,183.9	0	10,664,415
EU-ROW	export	160	25,061.82	198,677.1	0	2,486,206
EU-ROW	import	160	16,650.13	67,017.59	0	480,552
Total gas	export	461	11,422.83	122,366.5	0	2,486,206
Total gas	import	461	70,397.02	548,891	0	10,664,415

Source: Authors' calculation.

Table 4 shows that the EU traded more than twice as much energy with third countries as with itself (other EU Member States). The EU imported mainly liquid energy products, then solid energy products, and lastly trade in gas products. The trade in gas products was more intra-EU than between the EU and third countries. However, this table shows the energy dependence of the EU.

4. Results

The PPML estimation results are presented separately for exports and imports and separately for each type of energy product, namely solid, liquid, or gas (Tables 5–10). Each table of results has six columns because six separate regressions were performed for each of the subcomponents of LPI. Table 5 presents the estimates for solid energy product exports. Standard variables in the gravity model, such as the GDP of the reporting countries and the presence of a common border, showed significant and positive effects, as expected based on the current empirical literature [11,18–20]. The dummy variable groups were also positive and highly significant meaning that the export of solid food is more responsive in the case when the export is performed within the EU in comparison to the export between EU and third countries. In the case of logistics performance variables, only variable timeliness, which is delivery of solid energy products within the scheduled time, was the only positive and significant (Table 5).

Table 5. Estimation results for exports of solid goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*
(ln) gdp_i	0.304 ***	0.583 ***	0.210 ***	0.332 **	0.399 ***	0.154 *
	(3.44)	(3.74)	(3.47)	(3.08)	(3.47)	(2.35)
(ln) gdp_i	0.445 ***	0.466 ***	0.430 ***	0.448 ***	0.455 ***	0.421 ***
	(4.70)	(5.25)	(4.52)	(4.71)	(4.80)	(4.51)
contig	2.417 ***	2.459 ***	2.395 ***	2.423 ***	2.430 ***	2.381 ***
	(8.48)	(8.98)	(8.41)	(8.48)	(8.56)	(8.41)
lpi_comp (customs)	−0.312					
	(−0.75)					
lpi_comp (infrastructure)		−1.247 *				
		(−2.39)				
lpi_comp (international)			0.373			
			(1.08)			
lpi_comp (logistics)				−0.432		
				(−0.88)		
lpi_comp (tracking)					−0.784	
					(−1.50)	
lpi_comp (timeliness)						0.764 **
						(2.71)
group	1.454 ***	1.486 ***	1.444 ***	1.462 ***	1.468 ***	1.437 ***
	(6.01)	(6.32)	(5.93)	(6.03)	(6.10)	(5.92)
time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−4.887	−9.710 **	−4.268	−5.271	−5.865	−4.429
	(−1.55)	(−2.96)	(−1.33)	(−1.63)	(−1.85)	(−1.35)
Observations	7878	7878	7878	7878	7878	7878
Pseudo R2	0.490	0.519	0.490	0.491	0.496	0.495
RMSE	3.494	3.074	3.559	3.471	3.369	3.530

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

Table 6. Estimation results for exports of liquid goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*
(ln) gdp_i	0.383 ***	0.320 ***	0.450 ***	0.350 ***	0.368 ***	0.411 ***
	(4.69)	(3.36)	(5.97)	(3.92)	(4.44)	(5.56)
(ln) gdp_i	0.529 ***	0.529 ***	0.529 ***	0.528 ***	0.528 ***	0.529 ***
	(10.74)	(10.76)	(10.72)	(10.82)	(10.79)	(10.72)
contig	1.711 ***	1.699 ***	1.712 ***	1.705 ***	1.711 ***	1.709 ***
	(5.93)	(5.93)	(5.90)	(5.96)	(5.94)	(5.90)
lpi_comp (customs)	0.999 ***					
	(3.86)					
lpi_comp (infrastructure)		0.998 ***				
		(4.02)				
lpi_comp (international)			1.038 ***			
			(3.64)			
lpi_comp (logistics)				1.175 ***		
				(4.04)		
lpi_comp (tracking)					1.107 ***	
					(3.96)	
lpi_comp (timeliness)						1.182 ***
						(4.16)
groups	1.115 ***	1.116 ***	1.115 ***	1.113 ***	1.114 ***	1.114 ***
	(5.17)	(5.14)	(5.16)	(5.13)	(5.16)	(5.16)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−10.31 ***	−8.802 **	−12.12 ***	−10.24 ***	−10.62 ***	−12.50 ***
	(−3.84)	(−3.16)	(−4.60)	(−3.74)	(−3.96)	(−4.63)
Observations	13234	13234	13234	13234	13234	13234
Pseudo R^2	0.526	0.528	0.520	0.530	0.525	0.523
RMSE	3.144	3.096	3.115	3.142	3.119	3.084

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

Table 7. Estimation results for exports of gas goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*	*eng_export*
(ln) gdp_i	0.355	0.161	0.410	0.291	0.144	0.411
	(0.97)	(0.44)	(1.75)	(0.89)	(0.41)	(1.52)
(ln) gdp_i	0.449	0.445	0.453	0.442	0.438	0.454
	(1.72)	(1.72)	(1.67)	(1.73)	(1.72)	(1.74)
contig	−0.739	−0.747	−0.754	−0.696	−0.799	−0.763
	(−0.94)	(−1.03)	(−1.04)	(−0.91)	(−1.09)	(−1.00)
lpi_comp (customs)	0.460					
	(0.22)					
lpi_comp (infrastructure)		1.708				
		(0.93)				
lpi_comp (international)			−0.188			
			(−0.13)			
lpi_comp (logistics)				1.415		
				(0.62)		
lpi_comp (tracking)					1.890	
					(1.15)	
lpi_comp (timeliness)						−0.104
						(−0.06)
Groups	−1.304	−1.253	−1.335	−1.260	−1.249	−1.332
	(−1.71)	(−1.59)	(−1.67)	(−1.63)	(−1.56)	(−1.72)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−14.48	−13.86	−13.82	−16.24	−14.15	−14.08
	(−1.40)	(−1.36)	(−1.28)	(−1.42)	(−1.41)	(−1.22)
Observations	460	460	460	460	460	460
Pseudo R^2	0.397	0.419	0.396	0.407	0.414	0.396
RMSE	3.740	3.881	3.711	3.925	3.919	3.712

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

Table 8. Estimation results for imports of solid goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*
(ln) gdp_i	0.669 ***	0.676 ***	0.674 ***	0.649 ***	0.686 ***	0.667 ***
	(7.74)	(6.84)	(7.54)	(7.08)	(7.32)	(7.62)
(ln) gdp_i	0.626 ***	0.626 ***	0.626 ***	0.626 ***	0.626***	0.626 ***
	(14.49)	(14.50)	(14.46)	(14.48)	(14.49)	(14.49)
contig	1.672 ***	1.671 ***	1.673 ***	1.676 ***	1.673 ***	1.671 ***
	(5.51)	(5.48)	(5.53)	(5.49)	(5.53)	(5.55)
lpi_comp (customs)	0.267					
	(0.77)					
lpi_comp (infrastructure)		0.153				
		(0.47)				
lpi_comp (international)			0.451			
			(1.37)			
lpi_comp (logistics)				0.369		
				(1.08)		
lpi_comp (tracking)					0.162	
					(0.46)	
lpi_comp (timeliness)						0.373
						(0.98)
Groups	−0.995 ***	−0.995 ***	−0.997 ***	−1.000 ***	−0.995 ***	−0.995 ***
	(−4.22)	(−4.22)	(−4.24)	(−4.22)	(−4.24)	(−4.24)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−19.15 ***	−18.97 ***	−19.87 ***	−19.05 ***	−19.30 ***	−19.71 ***
	(−6.67)	(−6.63)	(−6.55)	(−6.49)	(−6.64)	(−6.45)
Observations	7878	7878	7878	7878	7878	7878
Pseudo R^2	0.415	0.415	0.416	0.416	0.415	0.415
RMSE	3.323	3.310	3.295	3.321	3.304	3.325

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

Table 9. Estimation results for imports of liquid goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*
(ln) gdp_i	0.603 ***	0.567 ***	0.608 ***	0.581 ***	0.588 ***	0.601 ***
	(6.70)	(5.54)	(7.13)	(5.81)	(5.75)	(6.38)
(ln) gdp_i	0.485 ***	0.485 ***	0.485 ***	0.484 ***	0.485 ***	0.485 ***
	(15.48)	(15.44)	(15.48)	(15.44)	(15.46)	(15.48)
contig	1.910 ***	1.909 ***	1.909 ***	1.912 ***	1.911 ***	1.909 ***
	(6.53)	(6.48)	(6.54)	(6.50)	(6.51)	(6.55)
lpi_comp (customs)	0.185					
	(0.61)					
lpi_comp (infrastructure)		0.281				
		(0.97)				
lpi_comp (international)			0.274			
			(0.73)			
lpi_comp (logistics)				0.305		
				(0.87)		
lpi_comp (tracking)					0.274	
					(0.73)	
lpi_comp (timeliness)						0.263
						(0.65)
groups	−0.409	−0.412	−0.409	−0.413	−0.411	−0.409
	(−1.91)	(−1.92)	(−1.91)	(−1.93)	(−1.92)	(−1.91)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−10.50 ***	−9.927 ***	−10.94 ***	−10.39 ***	−10.50 ***	−10.91 ***
	(−4.61)	(−4.10)	(−4.93)	(−4.45)	(−4.55)	(−4.91)
Observations	13234	13234	13234	13234	13234	13234
Pseudo R^2	0.370	0.370	0.370	0.370	0.370	0.370
RMSE	3.161	3.157	3.161	3.158	3.160	3.158

Source: Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

Table 10. Estimation results for imports of gas goods.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*	*eng_import*
(ln) gdp_i	0.314	0.133	0.301	0.236	0.126	0.356
	(1.15)	(0.62)	(1.53)	(0.91)	(0.56)	(1.38)
(ln) gdp_i	0.881 *	0.900 *	0.867 *	0.885 *	0.876 *	0.865 *
	(2.45)	(2.40)	(2.13)	(2.45)	(2.17)	(2.15)
contig	1.545	1.393	1.256	1.467	1.322	1.301
	(1.65)	(1.68)	(1.66)	(1.71)	(1.54)	(1.57)
lpi_comp (customs)	3.512					
	(1.57)					
lpi_comp (infrastructure)		3.087				
		(1.39)				
lpi_comp (international)			0.581			
			(0.63)			
lpi_comp (logistics)				3.856		
				(1.85)		
lpi_comp (tracking)					3.302 *	
					(2.17)	
lpi_comp (timeliness)						1.671
						(1.51)
Groups	1.926	1.969	1.931	1.995	1.990	1.948
	(1.78)	(1.75)	(1.73)	(1.82)	(1.74)	(1.74)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−37.65	−32.23	−25.83	−37.58	−32.54	−32.55
	(−1.54)	(−1.43)	(−1.41)	(−1.59)	(−1.45)	(−1.46)
Observations	460	460	460	460	460	460
Pseudo R^2	0.436	0.431	0.349	0.445	0.414	0.366
RMSE	4.249	4.398	4.070	4.179	4.541	3.974

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Author's calculation.

These results suggested that the export of energy products is less responsive to logistics performance, which significantly affects trade in consumption goods, for example. The recent empirical literature [11] shows that the subcomponents of the LPI have positive and significant effects on trade in consumption goods in the case of EU Member States. However, some other factors that could be used to explain trade in energy, such as the regulatory environment, natural resources, trade agreements, etc., could have a significant impact on the export of energy products.

Variable *dist* was clustered to accommodate serially correlated errors in trade within country pairs over time.

The results of the estimation in the case of export of liquid energy (Table 6) showed that gross domestic products of reporter and partner country were highly significant and positively affect exports of liquid energy products. The variable contiguity, which had a value of 1 if countries shared a common border also showed positive and highly significant results. As for the subcomponents of logistics performance, the results showed that all sub-components were affecting the trade in liquid energy products positively. That means that the higher the score of logistics performance the more it influences trade growth in liquid products.

In the case of exporting gas energy products (Table 7), the standard gravity variables were not significant, as well as all logistics performance indicators. The dummy variable group was also not significant, meaning that trade in the gas product is not sensitive to logistic components and regional trade path. However, in this analysis, the trade in the gas sample was the smallest, which means that the results might be the reason for the small variation.

Tables 8–10 present estimates of imports of energy products, again distinguishing between solid, liquid, and gas products. In the case of imports of energy products, gravity variables explain trade, with a high significance level in the case of solid and liquid products. However, as in the case of exports, the results of the estimation were not significant. The reason might again be the small sample size. Regarding the logistics performance variables, unlike in the case of exports, the estimates showed the opposite, insignificant results in all cases. What is interesting to observe is that the variable group was negative, which means that EU countries mostly import energy products (as Table 4 with descriptive statistics showed). These results clearly showed the trade path of energy products that is more import than export-orientation.

5. Discussion and Conclusions

This paper aimed to investigate the impact of logistics performance on bilateral trade in energy, focusing on 28 EU Member States. The EU Member States are generally highly dependent on foreign energy and their imports consist, to a large extent, of energy products. In addition, transport and storage energy is capital intensive and it is important for countries trading in energy to reduce the transport and other costs associated with trade. Energy products are different from all other commodities. Conventional energy resources are very unevenly distributed around the world, and energy-exporting countries and energy companies tend to have a monopoly position and are not given significant consideration by existing multilateral trade rules.

To achieve the aim of the research, this paper developed a structural gravity model in which six subcomponents of logistics performance were included in the standard gravity equation to determine which of the logistics elements are most susceptible to trading a particular type of energy product, namely solid, liquid, or gas. A group variable was also included in the model to control for regional effects, i.e., to quantify the difference when exporting or importing energy products between the EU Member States compared to exporting or importing energy products between the EU Member States and third countries. The estimation results showed that the standard gravity variables, GDPs of reporter and partner countries, representing economic mass, had highly significant and positive effects on bilateral trade in solid and liquid energy products. The variable contiguity, that is, the fact that the trading partners share a common border, also had a highly significant and positive effect on trade. This is quite understandable because, as mentioned earlier, transporting and storing energy is costly, and the closer the final trade destination, the lower the transport costs. In the case of trade in gas products, all the variables were insignificant and the reason for it might be in the small sample size and small variation.

In terms of logistical performance, the energy sector is very capital intensive, which means that significant costs are required to store and transport energy. Of all the observed subcomponents of logistics performance, in the case of exporting solid energy products, only "timeliness", namely delivery within the scheduled time, showed a positive and significant impact compared to exporting liquid energy products where all the subcomponents of logistics performance were highly significant and positive, but again, delivery of products within scheduled time had the largest impact. This information is of great importance to trading companies and managers who want to make their trade as efficiently as possible. The variable "timeliness" has also been shown in the empirical literature to be highly significant for trade in perishable goods such as food or chemical products [11]. Trade in gas was mainly regional due to the transport characteristics of these products and the results showed that logistics performance did not have a significant effect on trade in the gas products, except in the case of imports, where the variable "tracking", namely the ability to track and trace the transport of gas products, was significant. Moreover, the transportation of natural gas, for example, is mainly through pipelines, although the share of LNG trade is steadily increasing. Gas is also difficult to store, and a significant part of the trade takes place via fixed infrastructures, which poses major challenges for energy trade. The evident issues are the costly infrastructure and access to further transport networks. In the case of trade in gas products, each region relied on gas from a particular region, such as Europe relies on gas from Russia.

The variable "group" showed some interesting patterns. First, it was highly significant and positive for exports of solid and liquid products, while it was highly significant and negative for imports of solid energy products. These results imply that in bilateral trade, when an EU Member State exports solid or liquid products to another EU Member State, the export is higher than when an EU Member State exports to a third country. However, for imports, when an EU Member State imports solid energy products from another EU Member State, the value is lower than when it imports from a third country. The inclusion of the variable "group" was important to control for some regional effects. These results showed that the EU, as a whole, is very dependent on the exports of energy products from third countries. We must admit that this research has some limitations. First, the specifics of the energy market largely vary from other markets which were not taken into account in the estimations. Second, the analysis was based on the biennial data, as logistics performance is published every two years, so in the analysis included were only five years. As the time period (t) was relatively small, therefore, there may be a need to repeat the calculations when more time data is available, as the longer period might yield different results. Future research should also be extended in the sense that the modeling of energy trading was adapted to the specificities of the energy market. The year 2020 was affected by the COVID-19 pandemic, which had a major impact on the energy market. When the logistics performance index for 2020 and 2022 is published, it may provide new insights on this topic. Finally, this analysis was based on available country-level data, but further research could benefit from incorporating firm-level data into the analysis to a greater extent.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Products groups for the research.

Name of the Group	HS 4-Digit Heading
Solid	2701, 2702, 2703, 2704, 2705, 2708, 2714, 2715
Liquid	2706, 2707, 2709, 2710, 2711, 2712, 2713
Gas	2705

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