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How Road and Rail Transport Respond to Economic Growth and Energy Prices: A Study for Poland

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Abstract: Transport drives economies. This statement covers complex and multifaceted economic, environmental, and political issues. The literature mainly describes the unidirectional impact of transport on the economy, and far less often bilateral or reverse impacts. This is the context in which this study was conducted. The question of whether the economy (GDP and exports and imports) and energy prices (crude oil and diesel) have an impact on road and rail transport in Poland was examined. The research was based on correlation methodology and VAR modelling for the January 2010–March 2024 period (quarterly data). It was found that there is no sufficiently strong basis to speak of an inverse relationship, i.e., that the economy is the cause of transport. This confirms the majority of studies, but it has been shown that this relationship occurs in the current period. And this statement means that both road transport, which is developing, and rail transport, which is declining in Poland, are able to serve the economy on a continuous basis. Moreover, rail transport is positively affected by changes in fuel prices, but the basic energy resource used in rail transport is not fuel but electricity. Therefore, as fuel prices rise, investment in rail transport or combined transport can have positive economic and environmental effects in the future.

Keywords: road transport; rail transport; economic growth; fuel prices; transport electrification

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1. Introduction

Transport plays an important role in the economy. It provides for the movement of people and goods. Although it is necessary for the proper functioning of the economy, it does not in itself produce new goods, but rather consumes available resources. First among these are energy resources, but it also employs a lot of people in services, which on the one hand distracts them from other activities, but on the other hand provides them with work.

Despite its importance to the economy, transport is sometimes subject to criticism for its use of resources. In general, it is one of the sectors that contributes most to environmental degradation. Significant air pollution is caused by the use of fossil fuels in transport. Although most sectors of the economy are experiencing a reduction in their environmental impact, this is not the case for transport. Transport is responsible for around 25% of greenhouse gas emissions in the European Union, and this share is on the rise [1]. This trend is difficult to stop, as passenger transport continues to grow, and the volume of goods transported increases with economic development. The World Bank estimates that by 2030, passenger traffic is expected to increase by 50% and freight traffic by 70% [2]. Meanwhile, greenhouse gas emissions from transport could double by 2050 [3]. Road transport is particularly damaging to the environment [4].

The question of the relationship between the development of the transport sector and economic growth has been the subject of academic debate [5,6]. Tests have generally shown the existence of correlations and the validity of the thesis that economic growth is based on transport [7]. On the one hand, it has been noted that national transport systems are often unevenly distributed across regions, leading to uneven economic growth and

economic collapse in regions without developed transport [8]. On the other hand, the losses from uneven transport development are not only borne by specific regions, but also by the economy as a whole. This is due to the negative consequences of uneven transport development, especially regarding reductions in transport costs and travel time [9,10]; all efforts to improve this situation have brought good results [11,12]. As a result, it can be assumed that transport investment is a contributor to economic growth and that the relationship is monotonic [13]. This is due to the inflow of knowledge, capital, and people into well-connected regions [14–16]. Higher economic growth, accompanied by higher private investment and employment growth, tends to be achieved by countries that have invested more in infrastructure. Canning and Pedroni [17] show that infrastructure tends to generate long-term economic growth, but this investment requires large amounts of public capital, which reduces investment in other types of capital and, therefore, that there must be a level of infrastructure that optimises growth.

Studies that show the opposite, i.e., that transport development is a burden on regions, are rare. However, it has been shown that overinvestment has negative effects, and that it is necessary to maintain a certain optimality in order to obtain positive effects [18,19]. When constructing new transport investments, regional conditions, stages of economic development, and institutional factors should be taken into account [20]. Therefore, the net benefits of transport investment can theoretically be positive, zero, or negative, depending on how the economy is managed [21].

Countries can use transport to build their competitive advantage. Poland is a very good example of this. After joining the European Union, mainly due to cost attractiveness, Polish transport companies started to play an important role in the EU road transport market [22]. For Poland, transport is such an important sector that experts estimate that road freight transport contributes to 50% of the country's GDP [23], and Poland is the unchallenged leader in the European Union in all modes of transport.

Due to its importance, transport infrastructure has always been a political tool for decision-makers, treated as an instrument for influencing the economy, but at the same time as one of the most important public expenditures [24,25]. The theory presented in the literature identifies three ways in which infrastructure decisions are important for economic growth: (a) improving the overall productivity, (b) promoting technology transfer in the economy, and (c) increasing the profitability of transport companies [26]. Polish state policy in recent years has followed these three approaches, which is why Polish transport companies are undoubtedly successful in the European market.

A separate issue considered in the literature is the development of individual modes of transport. According to Deng et al. [21], there is a relationship between the resources allocated to road infrastructure and the long-term growth rate. The positive impact of roads and motorways on economic growth has been confirmed in a number of other papers [27–29]. However, extending these issues, according to Gherghina et al. [30], leads to a positive impact on economic growth for all categories of transport infrastructure except railways. And this result is particularly interesting because rail transport has been promoted in recent years as ecological, cheap, and promising. However, other studies have shown that rail transport also contributes to economic growth [27,29].

A comprehensive review of the evidence linking transport development and economic growth was undertaken by Cigu et al. [31]. They showed that five classes of relationships can be distinguished and found publications that confirm these assumptions. These are studies showing Granger causality between transport and economic factors:

1. Bidirectional [30,32–36];
2. Unidirectional [27,37–41];
3. Reverse unidirectional [42,43];
4. No causality [44];
5. Mixed results. For highly developed countries with significant saturation of transport infrastructure, there is little or no dependence; for developing countries with low saturation of infrastructure, its expansion is conducive to economic growth [45].

The economic dimension is one dimension of transport policy. Another dimension is the cost of the energy used as fuel in transport. To achieve the objectives of this study the most important considerations are those relating to crude oil and diesel, but also to their substitute, electricity. Nowadays, more emphasis is put on the development of fossil fuels that are less polluting, available in large quantities, and as efficient or more efficient than fossil fuels.

One of the most important issues to be addressed is the impact of rising fossil fuel prices on transport costs. It is anticipated that the long-term impact of rising fuel prices on the total cost of supply chains will be negative. Furthermore, when transport emissions tax is taken into account, the total cost of supply chains will increase even further. The impact of fuel prices on transport has been the subject of several studies, examining the effect on the profitability of transport companies [46], cost shifting to customers [47], modal shift [48], transport optimisation [49], and freight optimisation [50,51]. These studies have identified rising fuel prices as a common denominator affecting all of these areas.

The following research questions were posed to address the issue of the interaction between transport, economic growth, and fuel prices:

Q1: Is transport a lagged effect of economic growth and fuel prices?

This question corresponds to the third hypothesis formulated by Cigu et al. [31]. This assumption is rarely tested, which is why this question was chosen. The majority of academic literature on the subject addresses the causal relationship between transportation and economic growth. This is a topic that has been extensively researched and is well established in the field. However, the opposite direction may also be of interest. This relationship could be a possible lagged response of transport to demand reported by the economy.

Q2: Is the increase in fuel prices a disincentive for transport?

This question arises from the potential impact of the fuel market on the transportation sector. As it is one of the main costs, it can have a negative impact on transport. However, it may also be a cost that is passed on to the customer, in which case the demand reported by the economy will be more important.

Q3: Do road and rail transport respond in the same way to macroeconomic and fuel market stimuli?

This is an important question because a negative answer means that, under certain conditions, it makes economic sense to stimulate one mode of transport at the expense of the other. And so, it could be the basis for building government transport strategies.

The issue of transport is not solely a matter of economic growth; it is also a significant environmental concern. In particular, the excessive exploitation of fossil fuel resources and the subsequent production of greenhouse gases have become a major environmental issue. These issues have been the subject of research since the beginning of the 21st century, and thus are not a recent phenomenon [52,53]. A significant body of research has been conducted to examine the relationship between the growth of transportation and the growth of gross domestic product (GDP), with a particular focus on the environmental impact of these developments [54,55]. However, it should be noted that there are problems in separating these two issues. Sometimes the growth rate of transport, or more precisely the energy used in transport, is faster than economic growth; sometimes it is slower, but it is always positive [56].

One possible solution to these environmental issues could be to consider shifting the mode of transport from road to rail. It is often the case that economic development leads to an increased demand for logistics services, which in turn results in an increase in traffic. Railways can play an important role in the transport network, offering improvements to road and water transport [57]. It seems fair to say that rail freight has become a well-established and cost-effective mode of transport around the world. A number of studies have been carried out on this topic, and the existing literature provides some evidence that rail transport is relatively cheaper than road transport [58–61].

The problem of CO_2 emissions can be viewed globally by looking at total CO_2 emissions from all modes of transport (Figure 1) and at individual emissions (Figure 2). As road transport (of people and goods) is the most widespread, the total emissions are also the largest, accounting for about 74.5% of total transport emissions, of which 45.1% comes from passenger transport, and 29.4% from freight transport. Rail transport, on the other hand, accounts for only about 1% of CO_2 emissions.

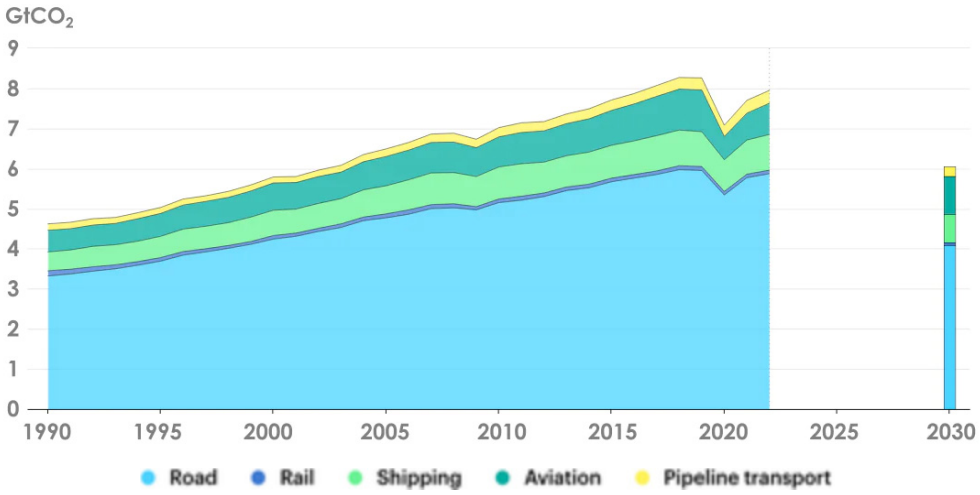

Figure 1. CO_2 Emissions from Transport. Source: International Energy Agency, Transport, 2023.

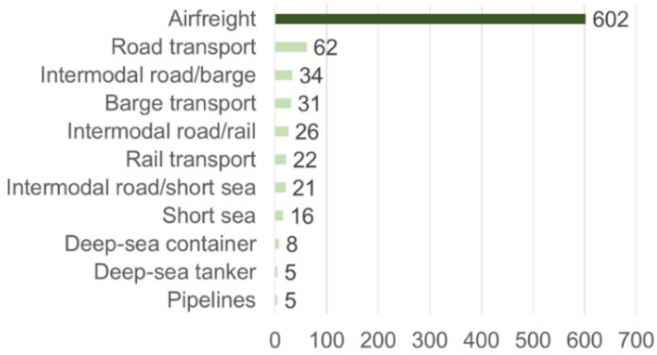

Figure 2. CO_2 Emissions from Freight Transport Operations (g CO_2/tonne-km). Source: European Clean Trucking Alliance.

The global CO_2 emissions of rail and road transport are contingent upon two factors: the total tonnage transported and the unit emissions. In terms of unit emissions, the advantage of rail transport over road transport is clear—per tonne–kilometre, road transport emits 62 g of CO_2 and rail transport emits 22 g, i.e., road transport is almost three times more polluting than rail transport. Although pipeline transport is the most advantageous in this respect—5 g of CO_2—rail transport is more flexible because it can carry many more types of goods than pipeline transport.

2. Materials and Methods

The research in this article is based on the premise of analysing the volume of land transport. Land transport is divided into two categories: rail and road. Concurrently, it is essential to consider the implications of international trade relations, which is why the division of transport into national and international transport is an important issue. The behaviour and sensitivity of these directions of transport to changes in fuel prices and economic development may be different. Therefore, the following variables have been chosen as key variables:

- domestic rail transport volume—Rail (domestic);
- international rail transport volume—Rail (international);
- domestic road transport volume—Road (domestic);
- international road transport volume—Road (international).

All transport volumes were originally expressed in thousands of tonnes of goods transported. However, they have been logarithmised in order to assess dependencies.

When considering the sensitivity of transport to changes in fuel prices, several issues should be kept in mind:

1. Economic calculation—the cost of fuel has a direct impact on the operating costs of transport companies, the price of services provided, and their financial results. It can be assumed that an increase in fuel prices will lead to an increase in the price of transport services, which may affect the competitiveness of individual modes of transport.
2. Psychological impact—the associated psychological impact is obviously difficult to verify, but negative information from world markets about conflicts, restrictions on oil production, or rising prices on world exchanges outweighs positive information. This means that oil prices are an important element in macro- and micro-economic policy making. Although crude oil is only a raw material for fuel production, its impact on markets is far-reaching.

In summary, the two aforementioned factors indicate that the potential impact on the transportation sector may be observed in the price of the final product, namely diesel oil, as well as in the price of the raw material, namely crude oil. Therefore, the impact of these two products was considered in the studies:

- wholesale diesel prices for the Polish market;
- Brent Crude Oil quotes for the ICE exchange.

Wholesale diesel prices were originally expressed in PLN/tonne and Brent Crude Oil in dollars/bbl. The original series have been logarithmised.

It is evident that fuel prices represent a significant cost factor in the context of transportation. However, in addition to the immediate cost implications, it is imperative to consider the broader economic growth and demand factors that shape the long-term development of the transportation sector. This can be described in general terms as:

- real economic growth;
- international trade—the export and import of goods.

Data on GDP and the sum of exports and imports were originally expressed in billions of PLN. Real data were used, i.e., the value of GDP and exports and imports were expressed at constant prices, i.e., 2009 prices were used.

These four variables were treated as macroeconomic variables which can potentially influence changes in transport.

A review of the literature reveals that it is challenging to ascertain the significance of fuel prices and economic growth for the volume and trajectory of land transport. The interconnections between fuel prices, the economy, and transport infrastructure can be intricate and contingent on numerous additional factors. However, causal studies should highlight general characteristics and identify directions of impact.

The data used for modelling cover the period from Q1 2010 to Q1 2024 and contain 57 quarterly observations for each variable.

The calculations were carried out in the EViews programme.

The data were logarithmised, allowing the regression coefficients of the econometric models to be interpreted as elasticity indicators.

A one-sided relationship was examined (Figure 3). Detailed diagnostic tests are to help determine whether the impact in question will be modeled based on levels or increments.

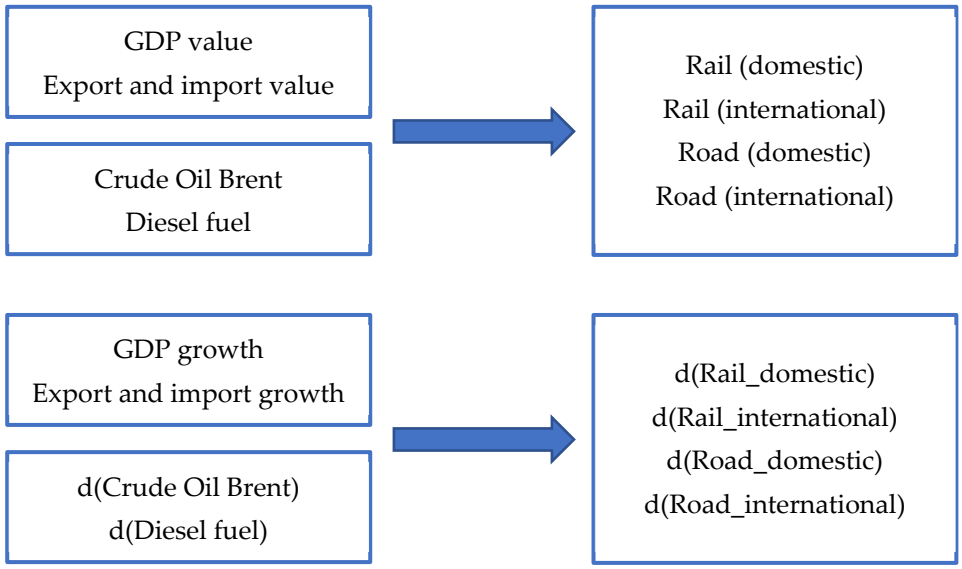

Figure 3. Potential impact of macro factors on transport.

The research was conducted in three principal parts:

1. Formation of the variables analysed.
2. Correlation analysis.
3. An analytical approach to the interrelationship between economic growth, fuel prices, and transportation.

Ad. 1. In the section *Formation of the variables analysed*, the empirical material was presented, and the main descriptive statistics were evaluated:

- the graphs of the logarithmic values of the time series of all the variables analysed were presented, and divided into transport-related variables and macro-variables;
- the seasonal component was removed from the data series and the Census X12 procedure was used;
- the statistics of the growth rate of each variable were determined according to the exponential model, together with an assessment of the significance of the growth rate;
- coefficients of determination were obtained for the exponential growth model before and after removal of the seasonal component;
- tests were used to assess the significance of the strength and stability of the seasonal component:
  - F-Test and Kruskal–Wallis test for the presence of seasonality assuming stability;
  - Moving Seasonality F-Test.

Ad. 2. In the *Correlation Analysis* section, an assessment was made of the correlation relationship between the time series:

- macro variables:
  - variable levels, i.e., a long-term relationship assessing the consistency of trends;
  - variable increases, i.e., assessing the strength and direction of short-term effects;
- consistency of transport trends with macroeconomic indicators;
- the relationship between short-term increases in transport volumes and increases in macroeconomic variables:
  - without time lags;
  - with a one-quarter time lag.

The procedure used in points 1 and 2 provides a comprehensive description of the formation and correlation of the values and increases in the assessed variables and may be useful in determining the appropriate form of the econometric model.

The actual study using econometric modelling was carried out in point 3 of the research part.

Ad. 3. Modelling the impact of macroeconomic variables on transport. The relationships were modelled using vector autoregressive VAR models [62,63]:

$$Y_t = A_0 D_t + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_k Y_{t-k} + e_t. \quad (1)$$

Model (1) was used for the variables:

1. Dependent variables d(Transport)—four models for each separate type of transport;
2. Independent variables concerning GDP growth or Export and import growth;
3. Independent variables concerning the fuel market d(Crude Oil Brent) or d(Diesel fuel).

The model (1) was transformed into an impulse response function [64], which assesses how the dependent variable responds to changes in the independent variables over time. The impulse response function values were presented in the form of graphs and were performed for each combination of explaining variables representing the economy and the fuel market, as well as for each type of transport as the explained variable.

3. Results

3.1. Formation of the Variables Analysed

As one of the most important sectors of the modern economy, the transport sector can be subject to a variety of influences, resulting in a specific shape of the time series of volumes (Figure 4). In the graphs shown, all the elements of classical economic series can be observed: trend, fluctuations, seasonal fluctuations, and random fluctuations. However, the changes in the structure of transport are also worth noting, which can largely be described by the trend.

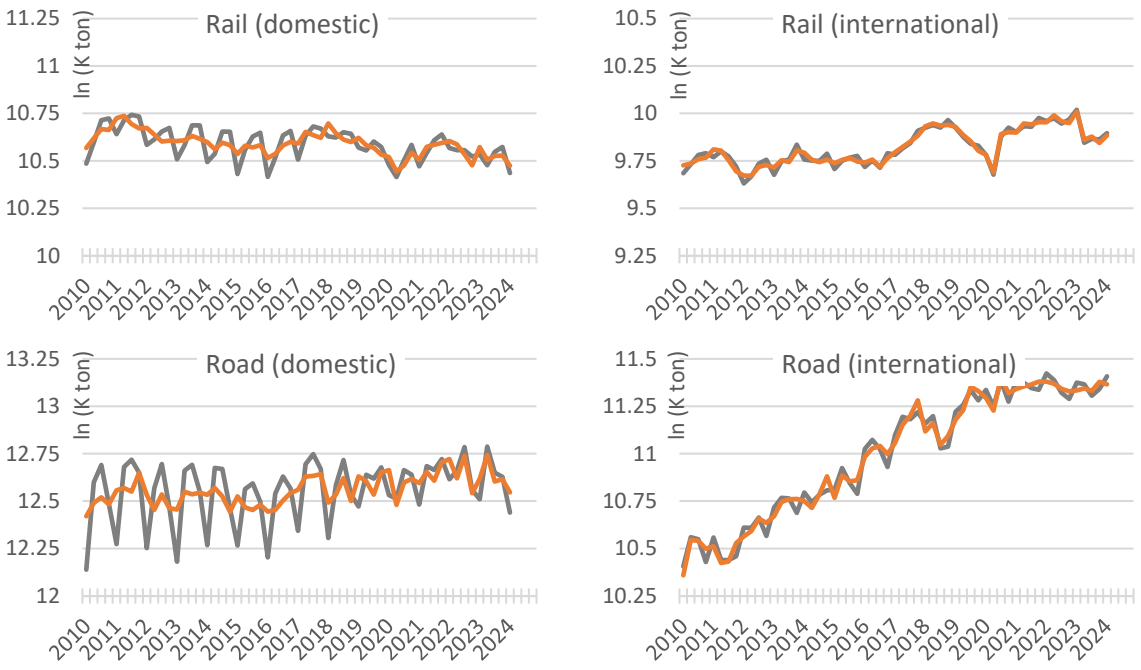

Figure 4. Transport volume—logarithmized data (gray) and seasonally adjusted data (orange).

International transport is characterised by a higher growth rate than domestic transport (Table 1). International road transport grew particularly fast, at an average of 7.80% per year, a rate well above economic growth and the international exchange rate (Table 3). International rail transport developed positively, but much more slowly at an average of 1.7% per year. Domestic road transport performed poorly, averaging 1.1% per year. On the other hand, domestic rail transport showed a clear decline over the period consid-

ered, with an average negative rate of −0.95% per year. The rate of change in transport was relatively stable (average values of the determination coefficient R^2 after removing seasonal variations).

Table 1. Transport growth statistics.

Transport	Beta (Quarterly)	Beta (Yearly)	*p*-Value	R^2 Without Season.	R^2 With Season.
Rail (domestic)	−0.24%	−0.95%	<0.005	0.4038	0.2031
Rail (international)	0.42%	1.70%	<0.005	0.5741	0.5555
Road (domestic)	0.28%	1.14%	<0.005	0.3552	0.0932
Road (international)	1.90%	7.80%	<0.005	0.9301	0.9195

Source: own calculations.

The effect of these changes is a change in the structure of transport. At the beginning of the period under review, in the first quarter of 2010, almost 54 million tonnes of freight were transported by rail, of which 69.0% was domestic and 31.0% international, while 220 million tonnes of freight were transported by road, of which 85.0% was domestic and 15.0% international.

On the other hand, in the first quarter of 2024, almost 52 million tonnes of freight were transported by rail (total increase of 4.0%), of which 63.2% was domestic (decrease of 5.8 p.p.) and 36.8% international (increase of 5.8 p.p.), while 342.5 million tonnes of freight were transported by road (total increase of 55.6%), of which 73.7% was domestic (decrease of 11.3 p.p.) and 26.3% international (increase of 11.3 p.p.).

Therefore, although both rail and road transport still outperform international transport in absolute terms, the relative dynamic advantage of international transport is clear.

Another difference between domestic and international transport is the sensitivity to seasonal variations (Figure 3 and Table 2).

Table 2. Seasonality of transport—test statistics.

Transport	Test for the Presence of Seasonality Assuming Stability		Moving Seasonality Test
	F-Value	Kruskal–Wallis Statistic	F-Value
Rail (domestic)	58.705 *	43.2204 *	2.451 *
Rail (international)	6.412 *	20.9272 *	1.085
Road (domestic)	65.536 *	40.1355 *	2.011 *
Road (international)	23.741 *	30.5829 *	0.912

Explanations: the table contains the values of the test statistics, symbol *—statistically significant. Source: own calculations.

In general, domestic transport (road and rail) is more sensitive to seasonal variations than international transport. However, it can be seen (Figure 5) that seasonal variations in transport are becoming less pronounced. In particular, for domestic road transport, the range of seasonal variations was from −27% to 17%, and in the most recent period it was from −11% to 5%. In all cases, seasonal fluctuations are statistically significant. In addition, domestic transport (road and rail) showed a significant reduction in seasonal fluctuations (significant results of moving seasonality test), which is beneficial from a transport planning point of view.

Macro variables illustrating the state of the economy have been divided into two categories. The first concerns production and trade. Here we have GDP and exports and imports, which developed quite rapidly, at an average annual rate of 3.56% and 5.95%, respectively, and also relatively stably, with high values of the coefficient of determination R^2. The second group concerns the fuel market, and here we have Brent Crude Oil and Diesel fuel, which developed unstably—very low values of the determination coefficient R^2. This means very frequent, irregular changes in different directions. The combined effect

is an average annual decrease in the price of Brent Crude Oil of −2.57% and an average annual increase in the price of Diesel fuel of 2.17%. Here it should be noted that these results can be misleading to a large extent, as they depend heavily on the period covered by the assessment. These effects are shown in Figure 6 and in Table 3.

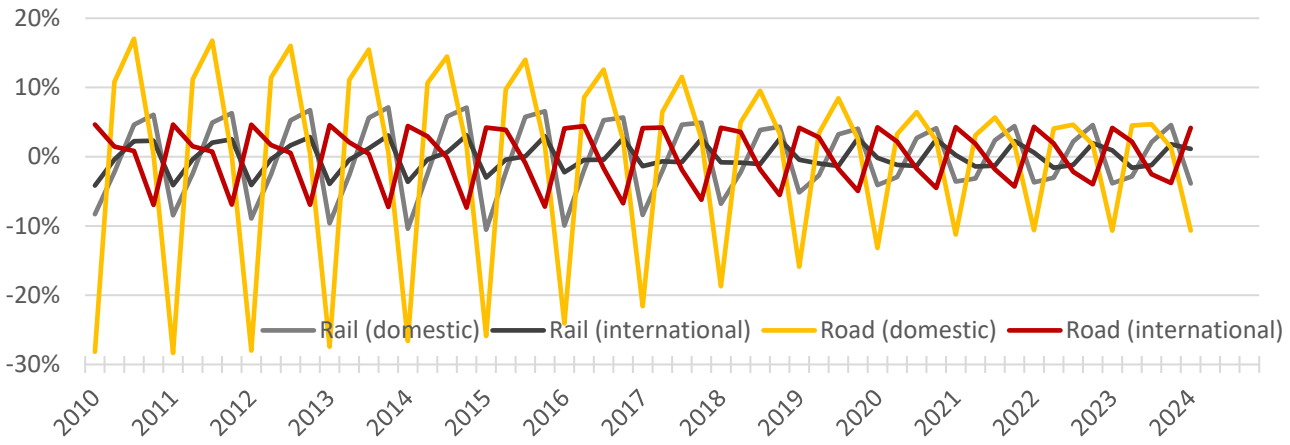

Figure 5. Transport—seasonal cycles.

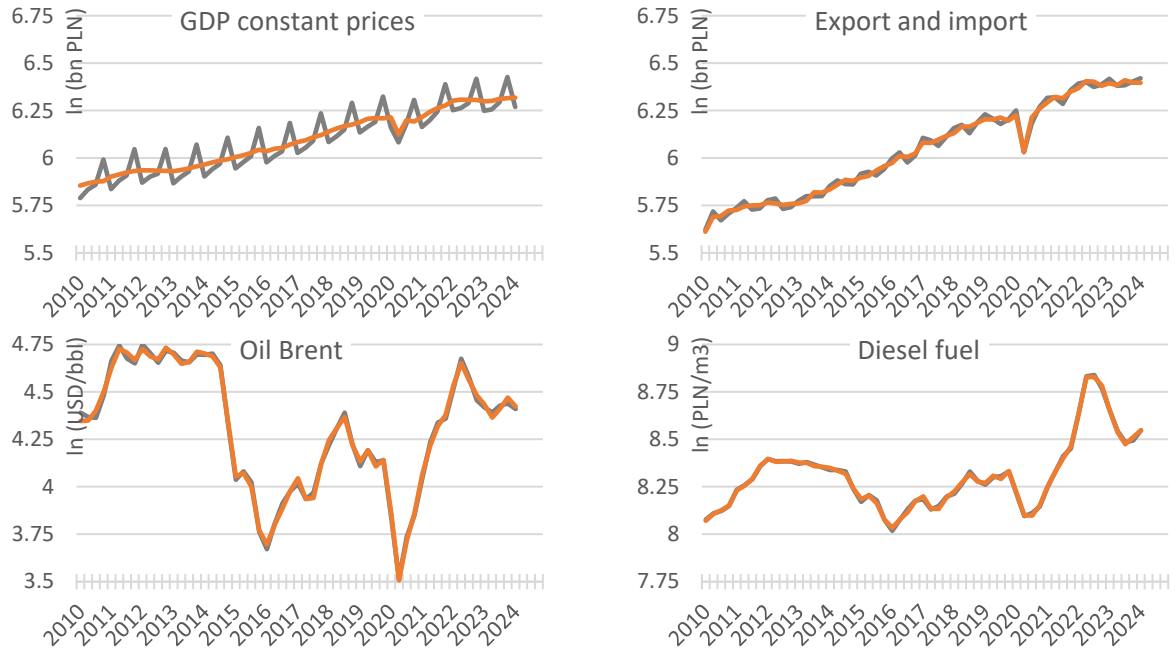

Figure 6. Macro variables—logarithmized data (gray) and seasonally adjusted data (orange).

Table 3. Macro variables growth statistics.

Macro Variables	Beta (Quarterly)	Beta (Yearly)	*p*-Value	R^2 Without Season.	R^2 With Season.
GDP const. prices	0.88%	3.56%	<0.005	0.9786	0.8139
Export and import	1.46%	5.95%	<0.005	0.9727	0.9654
Oil Brent	−0.65%	−2.57%	0.012	0.1096	0.1124
Diesel fuel	0.54%	2.17%	<0.005	0.2335	0.2315

Source: own calculations.

It is worth noting that GDP and exports and imports grew faster than rail transport (domestic and international) and road transport (domestic). Only international road transport grew faster than GDP and exports and imports.

Economic variables and fuel market variables differ not only in terms of stability of growth but also in terms of sensitivity to seasonal fluctuations (Figure 7, Table 4).

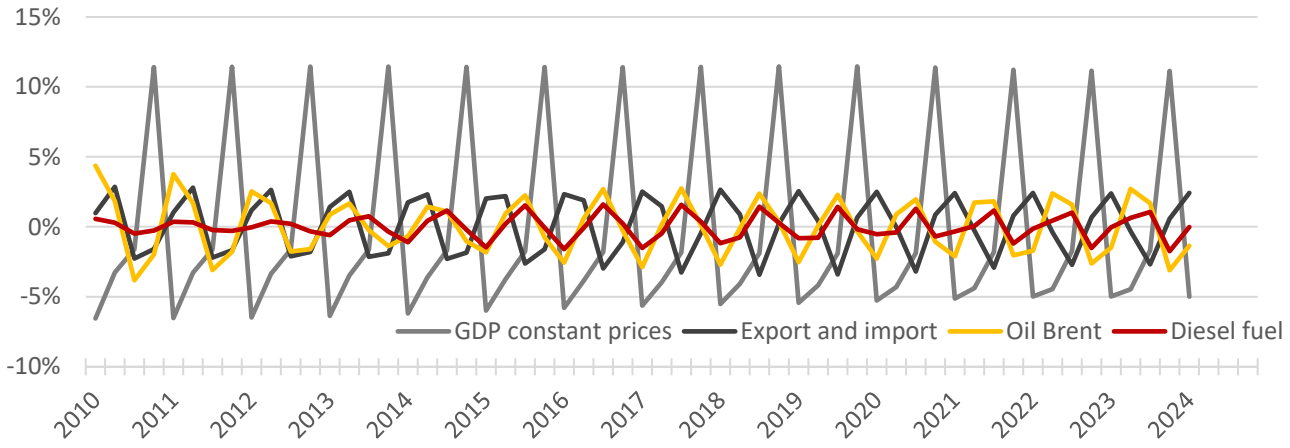

Figure 7. Macro variables—seasonal cycles.

Table 4. Seasonality of macro variables—test statistics.

Macro Variables	Test for the Presence of Seasonality Assuming Stability		Moving Seasonality Test
	F-Value	Kruskal–Wallis Statistic	F-Value
GDP const. prices	939.650 *	49.9520 *	0.096
Export and import	10.264 *	33.8752 *	1.574
Oil Brent	0.952	6.3781	1.042
Diesel fuel	1.969	6.7925	0.622

Explanations: the table contains the values of the test statistics, symbol *—statistically significant. Source: own calculations.

Very strong seasonal variations are observed for GDP, with much weaker but statistically significant variations observed for exports and imports (significant results of the test for the presence of seasonality assuming stability). On the other hand, fuel prices, both world Brent Crude Oil and domestic Diesel fuel, do not show significant seasonal variations (in the same test). There were no significant changes in the seasonal pattern over the period studied (results of moving seasonality test).

3.2. Correlation Analysis

The study of the interdependencies of the levels of the variables (Table 5) revealed effects that are consistent with the general trends of the variables. Thus, we can speak of average or strong relationships between international rail transport, national and international road transport, and GDP, as well as exports and imports. This is the effect of consistent, positive trends. On the other hand, the relationship between domestic rail transport and GDP, as well as export and import, is negative, which is the effect of opposite trends.

The relationship between transport volumes and fuel prices is much more complex. This complexity is mainly due to changes in fuel price trends. In general, however, it can be said that, in the long term, the price of Diesel fuel is more important for road transport than the price of Brent Crude Oil, which is an obvious consequence of the fact that vehicles are powered by Diesel fuel and not by Brent Crude Oil. In the case of rail transport, on the other hand, the dependencies are more coincidental, as the main fuel used to power rail vehicles is electricity. However, the price of electricity depends on the price of energy resources, including potentially Brent Crude Oil. However, if this effect is to be visible, it should be confirmed by the correlation of increases.

Table 5. Correlations between transport and macroeconomic indicators—variable level statistics.

Macro Variables	Transport			
	Rail (Domestic)	**Rail (International)**	**Road (Domestic)**	**Road (International)**
GDP const. prices	−0.5596 $p = 0.000$	0.8063 $p = 0.000$	0.6420 $p = 0.000$	0.9539 $p = 0.000$
Export and import	−0.5420 $p = 0.000$	0.8229 $p = 0.000$	0.6440 $p = 0.000$	0.9592 $p = 0.000$
Oil Brent	0.4761 $p = 0.000$	−0.0402 $p = 0.767$	0.0627 $p = 0.643$	−0.4542 $p = 0.000$
Diesel fuel	−0.1505 $p = 0.264$	0.4981 $p = 0.000$	0.4915 $p = 0.000$	0.3430 $p = 0.009$

Explanations: first number—correlation coefficient, second number—significance level. Source: own calculations.

Correlation studies on levels can suffer from a rather serious flaw, namely the apparent correlation. Therefore, complementing this study with a correlation study on variable increments (Table 6) allows for a better assessment of the real interdependencies.

Table 6. Correlations between transport and macroeconomic indicators—variable increases statistics.

Macro Variables	Transport			
	d(Rail_ Domestic)	**d(Rail_ International)**	**d(Road_ Domestic)**	**d(Road_ International)**
d(GDP const. prices)	0.3362 $p = 0.011$	0.5586 $p = 0.000$	0.3661 $p = 0.006$	0.2457 $p = 0.068$
d(GDP const. prices) (−1)	0.0844 $p = 0.540$	−0.3736 $p = 0.005$	−0.1534 $p = 0.264$	−0.3311 $p = 0.014$
d(Export and import)	0.3643 $p = 0.006$	0.6107 $p = 0.000$	0.3363 $p = 0.011$	0.3293 $p = 0.013$
d(Export and import) (−1)	0.1193 $p = 0.386$	−0.4075 $p = 0.002$	−0.0615 $p = 0.655$	−0.3127 $p = 0.020$
d(Oil Brent)	0.3556 $p = 0.007$	0.4174 $p = 0.001$	0.1337 $p = 0.326$	0.0163 $p = 0.905$
d(Oil Brent) (−1)	0.2108 $p = 0.122$	−0.0327 $p = 0.813$	−0.0026 $p = 0.985$	−0.3381 $p = 0.012$
d(Diesel fuel)	0.1233 $p = 0.365$	0.2066 $p = 0.127$	0.0852 $p = 0.532$	−0.0055 $p = 0.968$
d(Diesel fuel) (−1)	0.0852 $p = 0.536$	0.0534 $p = 0.698$	−0.0220 $p = 0.873$	−0.2379 $p = 0.080$

Explanations: first number—correlation coefficient, second number—significance level; (−1)—transport delayed by 1 quarter relative to macro variables. Source: own calculations.

Correlation studies of variable increases have shown a positive correlation between transport, GDP, and exports and imports. Moreover, this is generally a lag-free relationship, i.e., the increase in GDP and exports and imports corresponds to the average increase in national and international transport by all modes. The effect is statistically significant. Study with a time lag gives different results in terms of the sign of the relationship and the significance and can generally be considered as random.

The results concerning the relationship between road transport and the prices of Brent Crude Oil and Diesel fuel are very interesting. In general, it appears that the increase in the volume of road transport is independent of changes in fuel prices, i.e., regardless of whether fuels become cheaper or more expensive, the changes in the volume of transport are related only to changes in the demand and supply of products, illustrated by changes in GDP and exports and imports, not with fuel prices. However, there is a very weak negative lagged disturbance, i.e., road transport, mainly international, reacts negatively to changes in fuel prices with a 1 quarterly lag.

In the case of rail transport, there is an average but statistically significant relationship with changes in the price of Brent Crude Oil. Paradoxically, this is a positive relationship, meaning that as the price of Brent Oil rises, rail transport increases. This effect may be caused by two factors: the use of cheaper rail transport when oil prices rise, and the indirect effect of oil price rises on economic growth. This first explanation may be particularly important as changes in the volume of rail transport turn out to be completely independent of changes in the price of Diesel fuel.

3.3. Model Approach to the Interaction Between Economic Growth, Fuel Prices and Transport

In the case of rail transport, there is an average but statistically significant relationship with changes in the price of Brent Crude Oil (Table 7). Paradoxically, this is a positive relationship, meaning that as the price of Brent Oil rises, rail transport increases. This effect may be caused by two factors: the use of cheaper rail transport when oil prices rise, and the indirect effect of oil price rises on economic growth. The first explanation may be particularly important as changes in the volume of rail transport turn out to be completely independent of changes in the price of Diesel fuel.

Table 7. VAR model—rail transport as a dependent variable.

Independent Variables	Dependent Variable d(Rail_Domestic)	Independent Variables	Dependent Variable d(Rail_International)
d(Rail_domestic) (−1)	−0.299354 (0.14434) [−2.07398]	d(Rail_international) (−1)	0.148958 (0.16011) [0.93035]
d(Rail_domestic) (−2)	−0.008783 (0.13966) [−0.06289]	d(Rail_international) (−2)	0.219924 (0.16067) [1.36882]
d(GDP const. prices) (−1)	−0.212924 (0.36334) [−0.58603]	d(Export and import) (−1)	−0.763054 (0.19610) [−3.89118]
d(GDP const. prices) (−2)	−0.394517 (0.38110) [−1.03521]	d(Export and import) (−2)	−0.213012 (0.21055) [−1.01168]
d(Oil Brent) (−1)	0.151709 (0.05040) [3.01020]	d(Diesel fuel) (−1)	0.269107 (0.11407) [2.35909]
d(Oil Brent) (−2)	−0.086045 (0.05369) [−1.60273]	d(Diesel fuel) (−2)	−0.236370 (0.11012) [−2.14644]
C	0.000782 (0.00719) [0.10883]	C	0.014298 (0.00702) [2.03637]
R-squared	0.293728	R-squared	0.324697

Explanations: first number—regression coefficient, second number—standard errors, third number—t-statistics. Source: own calculations.

It appears that domestic rail transport is significantly negatively affected by its own delays (concerning delays of one quarter). The effect of this is the negative trend in levels which was described above. There was a negative, although insignificant, effect of GDP changes on this transport (concerning delays of 1 and 2 quarters), which in turn is the effect of different long-term trends in variable levels. However, very importantly, there was a highly statistically significant and positive effect of changes in Brent Oil prices on rail transport (concerns delays of 1 quarter). This is a very important effect because it shows that in a situation of rising road transport costs, rail transport can be a potentially attractive alternative.

In the model of international rail transport, a positive but statistically insignificant impact of our own delays was found (concerning delays of 1 and 2 quarters). There was a

negative and statistically significant impact of changes in exports and imports (concerns delays of 1 quarter). This is not an error because, together with the information in Table 6, it means that international rail transport reacts statistically and positively to changes in exports and imports without delays. This means that international rail transport allows international trade to be serviced in real time. The effect of changes in the price of Diesel fuel is more difficult to assess, as it is significantly negative for one delay and significantly positive for two delays, i.e., it has a cancelling effect. With reference to the results of Table 6, this confirms the conclusion that international rail transport is independent of changes in fuel prices.

In order to better illustrate the impact of economic growth, changes in exports and imports, and changes in the fuel market, impulse response functions were determined for various combinations of independent variables (Figure 8).

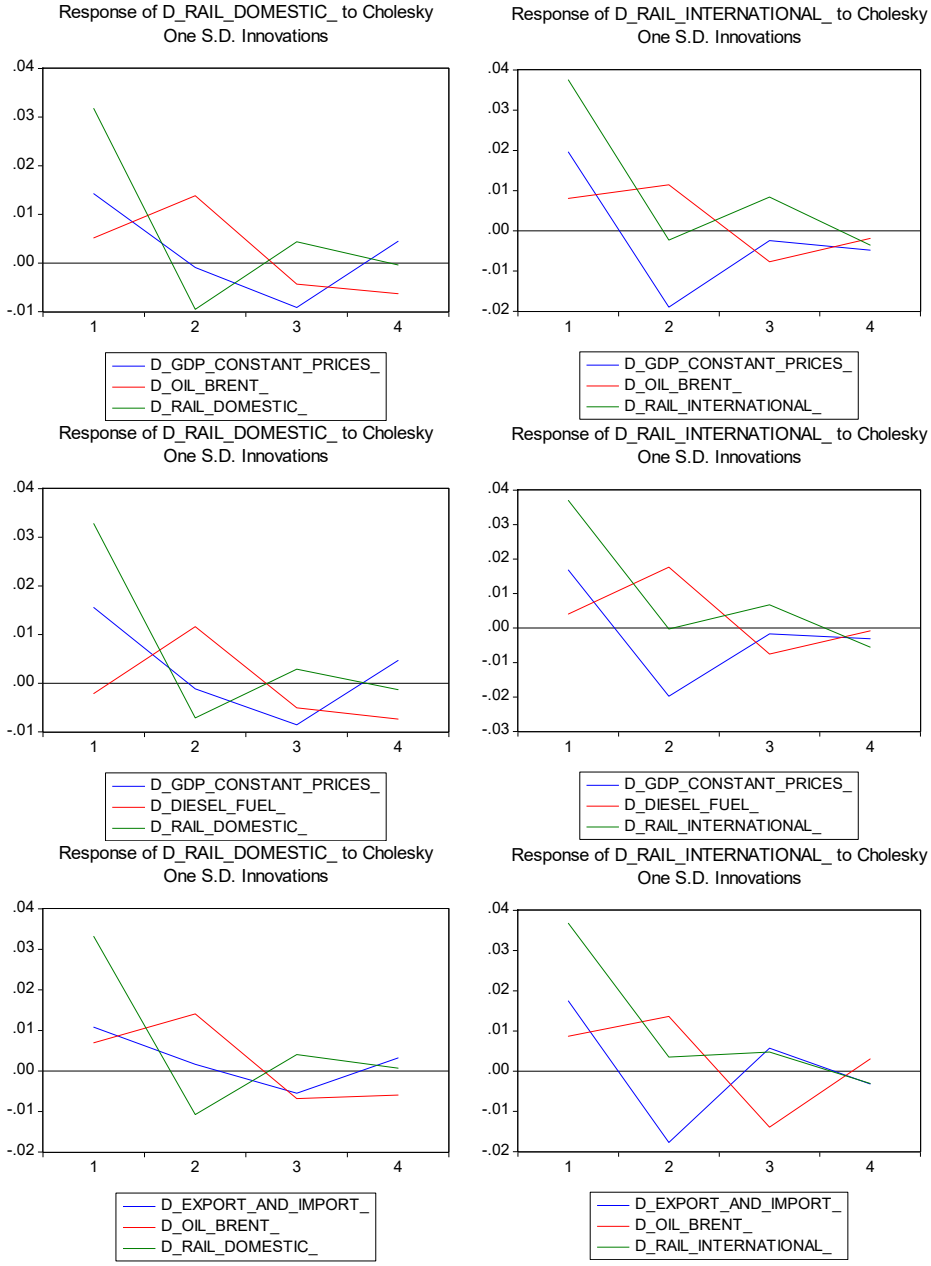

Figure 8. *Cont.*

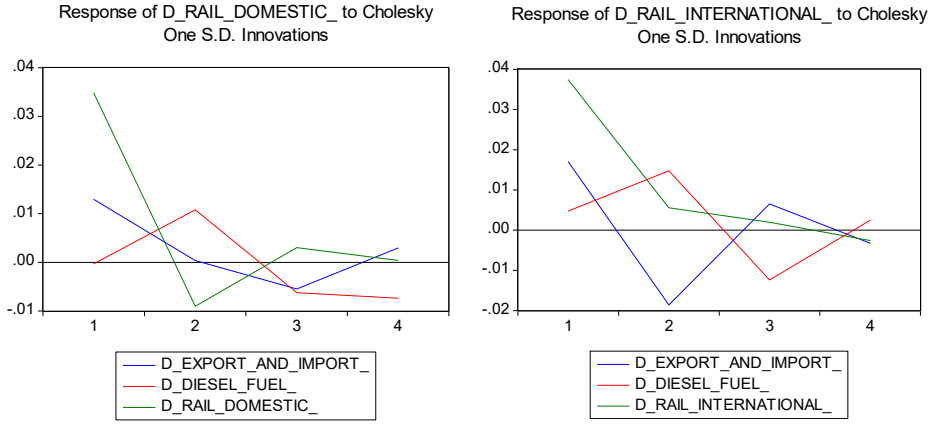

Figure 8. Impulse response function—rail freight transport as an effect.

The key here is to confirm the previously observed correct observations regarding the impact of economic variables and the fuel market on rail transport. It turns out that there is always a positive impact of changes in Brent oil prices on changes in rail transport, and a relative independence from changes in diesel fuel. At the same time, there is a positive relationship between a quarterly lag in economic growth and changes in exports and imports.

The second model evaluated concerns the impact of economic growth and fuel prices on the domestic road transport market and the dynamics of exports and imports and fuel prices on the international road transport market (Table 8).

Table 8. VAR model—road transport as a dependent variable.

Independent Variables	Dependent Variable d(Road_Domestic)	Independent Variables	Dependent Variable d(Road_International)
d(Road_domestic) (−1)	−0.709283 (0.13862) [−5.11666]	d(Road_international) (−1)	−0.235191 (0.14968) [−1.57127]
d(Road_domestic) (−2)	−0.512563 (0.13770) [−3.72241]	d(Road_international) (−2)	−0.066552 (0.13784) [−0.48283]
d(GDP const. prices) (−1)	0.292942 (0.67385) [0.43473]	d(Export and import) (−1)	−0.292793 (0.25459) [−1.15006]
d(GDP const. prices) (−2)	0.499609 (0.67347) [0.74184]	d(Export and import) (−2)	0.088799 (0.26197) [0.33897]
d(Diesel fuel) (−1)	0.093761 (0.19077) [0.49148]	d(Diesel fuel) (−1)	−0.123163 (0.17199) [−0.71612]
d(Diesel fuel) (−2)	−0.098680 (0.18392) [−0.53653]	d(Diesel fuel) (−2)	−0.142593 (0.17304) [−0.82406]
C	−0.002780 (0.01259) [−0.22080]	C	0.024618 (0.01048) [2.34834]
R-squared	0.396802	R-squared	0.173254

Explanations: first number—regression coefficient, second number—standard errors, third number—t-statistics. Source: own calculations.

Although these models do not have high coefficients of determination, it was decided to present them because the independent variables are potentially important determinants of road transport.

For the growth of domestic road transport, the most important and statistically significant explanatory variable is own delays. They have a negative effect. As a result, the evolution of domestic road transport is very weak, although positive. In the case of international transport, its delays are not statistically significant, and the trend is much more positive. A positive trend for international transport in the incremental model is also illustrated by a positive, statistically significant intercept.

Characteristic of both models is the lack of influence of lagged increases in macroeconomic variables and lagged variable increases in fuel prices on current road transport. This effect does not contradict the correlation results but complements them. It shows that the interdependencies in the transport market are quick-response interdependencies rather than potentially delayed interdependencies.

Figure 9 shows all combinations of the impact of macroeconomic variables and the fuel market on road transport. It shows that domestic road transport is virtually independent of lagged changes in the price of Brent Crude Oil and Diesel fuel. On the other hand, international transport shows a negative combined effect, which is unfavourable. However, it is important to note that road transport also reacts to changes in economic indicators. In general, this means that road transport (domestic and international) is able to meet the demand reported by the economy, but with a negative sensitivity to changes in fuel prices (this is particularly the case for international transport).

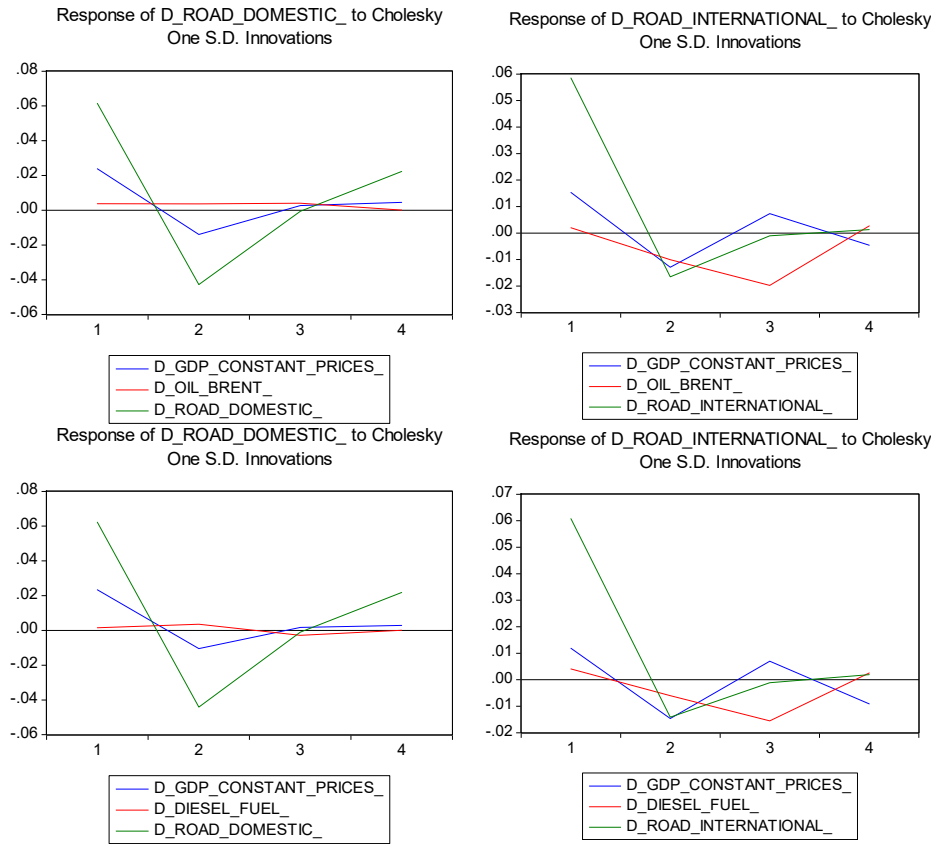

Figure 9. *Cont.*

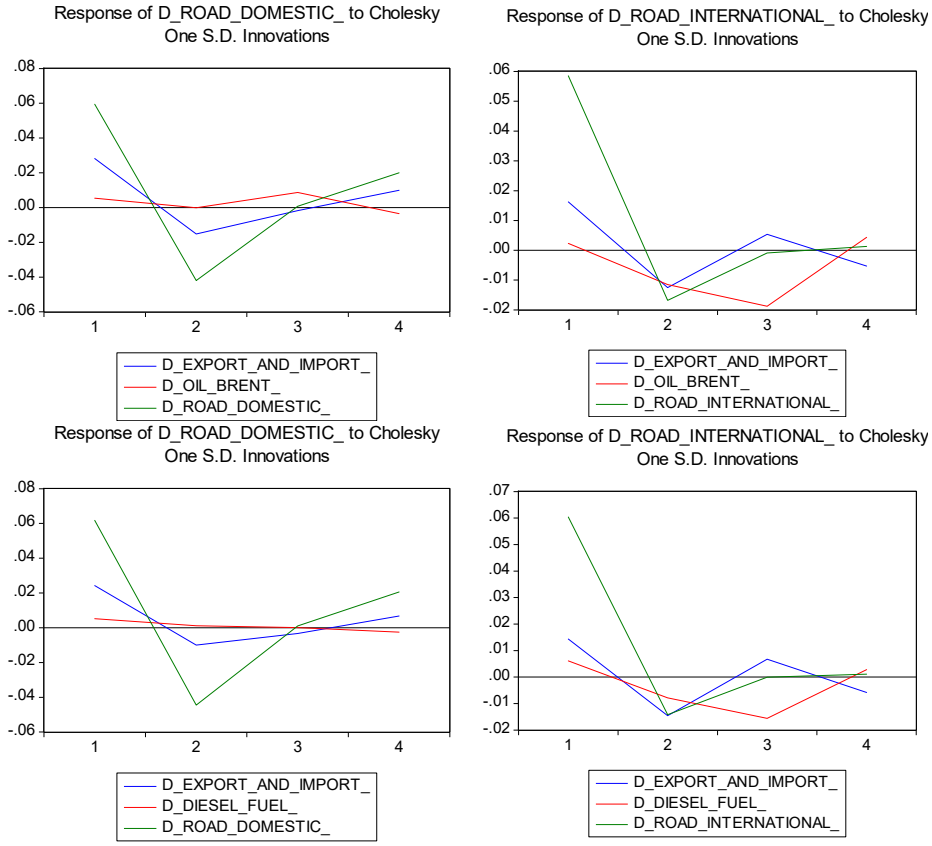

Figure 9. Impulse response function—road freight transport as an effect.

4. Discussion

The statement that the economy needs efficient transport is obvious. Discussion should focus on the conditions under which transport can be considered efficient. Previous technological innovations have led people to travel more often and over longer distances, international trade in goods is still growing, innovations that make transport cheaper are also making it more widespread [65], and contemporary thinking about moving away from fossil fuels does not change this [66]. This thinking usually leads to the promotion of rail transport as an ecological alternative to road transport. Measures are being taken to make rail transport more efficient so that it can provide the service values that freight forwarders find in road transport. The modernisation of rail transport has the potential to enhance its reliability, accessibility to freight forwarders, frequency of services, and the ability to provide shipments with a shorter delivery time [67]. The proposal is to establish a comprehensive, high-speed, fully electrified rail system on a continental scale in Europe [68] and globally. This would facilitate the resolution of the issue of unequal economic development, which is a consequence of unequal transport accessibility [69].

Undoubtedly, the advantage of road transport over rail is the flexibility of transportation routes. Road transport can easily deliver practical products to any location, whereas rail transport is strictly limited by available rail infrastructure. However, rail or combined transport is becoming increasingly important for very long distances. In terms of capacity, however, the advantage of rail over road is clear. This is especially true when large quantities of goods need to be transported at the same time. For small loads and short distances, the advantage of road transport increases. For large loads and long distances, reduced operating costs give rail an advantage. However, rail is not as fast as road transport. Road transport is usually faster than rail transport for shorter distances due to fewer restrictions on the availability of routes and the possibility of delivering goods directly to the destination.

Rail transport, with its greater capacity and lower fuel consumption, can ensure lower operating costs per unit of freight transported, which can translate into savings for logistics companies. However, investment in rail transport is very expensive. Compared to other modes, road transport is characterised by relatively low initial costs. Investment in a vehicle and the necessary permits are easily available to entrepreneurs. The disadvantages of road transport include its environmental impact; road transport generates more CO_2 emissions, which is important from the point of view of sustainable development and ecology.

However, the development of rail transport faces certain infrastructure barriers, the most important of which are the need to cross the transport line, a much more developed road network, and the lack of space for rail infrastructure, especially in cities; it is also subject to social barriers related to society's acceptance of new investments, road habits, or certain historical events [70]. Meanwhile, the cost-effectiveness of shifting freight from road to rail is likely to be limited for distances above 300 km. This is the concept of efficient green freight corridors. According to this, it would be possible to shift as much as 1/3 of road freight to other modes of transport, such as rail or water, by 2030 [71]. How to deal with local barriers can be described using four barrier effect indicators: travel time, choice, catchment area, and service efficiency [72]. An interesting solution that has been tested in terms of global and local development is to put motorways and railways in tunnels.

In any case, transport and supply chain costs are expected to rise in the short term. Transport companies, as well as the government, will have to reassess their strategies to address cost challenges as fuel prices increase impact profitability. This may lead them to shift their supplier base to nearby locations or increase prices to customers, reducing their competitive advantage, or absorb higher fuel costs, reducing their profitability [73].

The above-mentioned issues, although important, were only of indirect interest in the present study. The issues considered in this article are much more important for the formation of the economic policy of the state and a certain vision of the development of land transport, and will be only somewhat important for customers and logistics companies. The research carried out in the paper has made it possible to verify three issues, i.e., the sensitivity of rail and road transport to the costs resulting from changes in fuel prices and demand for goods from the economy (represented as GDP), the export and import of goods, as well as detecting differences in the reactions of road and rail transport.

These environmental issues mean that transport solutions are being sought that meet the expectations of various interest groups while at the same time reducing negative impacts on the environment. Rail transport is perceived as such. However, in order to be treated as a real alternative to road transport, it must also meet other conditions that make it competitive.

This solution seems reasonable because, although governments and international organisations are promoting the use of rail freight, road transport still accounts for a larger share of freight transport than rail [74,75]. It is therefore necessary to find a compromise solution that ensures speed of delivery, a stable delivery price, and the lowest possible environmental impact. This is very important because sometimes the advantage of road transport over rail transport is seen as being faster and more flexible. This is probably important from a microeconomic point of view because it ensures faster and more efficient delivery. From a macroeconomic point of view, however, it is no longer decisive, as each mode of transport has the capacity to serve the economy and, in addition, rail transport is becoming more important as fuel prices rise.

Although the research results show the advantages of rail transport, taking into account the fact that the policies developed to promote modal shifts do not bring benefits, it is necessary to determine the behaviour of carriers in terms of their choice of transport mode. And here we can say that such a key factor is the time of transport [76–78], as well as the reliability of transport services and the availability of the means of transport [79,80]. However, even if the study has shown that there are no differences in the response of road and rail transport to changes in demand at the macroeconomic level, unfortunately

these data are limited by the quarterly data period, which means that short-term responses cannot be captured here.

5. Conclusions

With regard to the specific research questions formulated in the introduction to the study, it can be noted that:

Ad. Q1. Transport cannot be considered as a lagged effect of the economic model. However, the attribution that it is a simultaneous effect cannot be rejected. This is true for all types of transport considered. Similarly, it cannot be assumed that there is a lagged response to changes in fuel prices.

Ad. Q2. Road transport turns out to be independent of changes in fuel prices. On the other hand, rail transport reacts positively to changes in fuel prices. This positive reaction may mean that when fuel prices rise, haulers look for cheaper modes of transport and may therefore turn to rail transport. However, even if such an effect occurs, it is not permanent as rail transport is generally in decline.

Ad. Q3. Road and rail transport react differently to stimuli from the economy and the fuel market. First of all, the long-term trend and the reaction to changes in fuel prices are different. However, the response to economic growth is similar.

Research for Poland shows that the development of rail transport, especially domestic transport, is in decline compared to road transport. Can we assume that this is justified on the basis of the research results? Certainly, the generally perceived convenience of road transport is definitely greater than that of rail, but it is worth taking a look at some of its advantages, which are also shown in this study:

1. Firstly, no fundamental differences were found between road and rail transport in terms of serving the economy from a macroeconomic point of view. Both road and rail transport responded positively to changes in economic growth and changes in exports and imports, and this response usually occurred without time lag. Therefore, both modes of transport offer the possibility of providing a current service to the economy.
2. Another point worth emphasising here is the sensitivity to changes in fuel prices. As expected, road transport is much more sensitive than rail transport. Although the results were not statistically significant here, trends are likely to be important in addition to statistical significance. And these give an advantage to rail transport. The significant variability of fuel prices means that road transport costs are variable and potentially difficult to predict, even in the short term. In the longer term, road transport costs are expected to increase, both because of the limited raw material (fuel) and because of tax issues (environmental changes). Therefore, the development of rail transport seems to be a good alternative, providing a potential advantage to an economy with a developed rail infrastructure. Taking these observations into account, investment in rail transport, modernisation of existing infrastructure, and construction of new infrastructure are recommended. Combined road–rail transport should probably be considered as a recommended solution.

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