Współczesna Gospodarka

Contemporary Economy
Electronic Scientific Journal
Współczesna Gospodarka (ug.edu.pl)

Vol. 17 Issue 2 (2023) 29-49
*ISSN*2082-677X
DOI 10.26881/wg.2023.2.03

ASYMMETRIC IMPACT OF DIFFERENT TYPES OF ROAD TRANSPORT ON ECONOMIC GROWTH IN THE VISEGRAD GROUP COUNTRIES: AN EMPIRICAL ANALYSIS OF THE NARDL FRAMEWORK

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Abstract

The contemporary economy depends on an effective transportation system, and road haulage assumes a crucial function in fostering dynamic economic growth and commerce. This article aims to investigate the influence of various road transportation modes on economic growth in the Visegrad countries. In this study, the nonlinear autoregressive distributed lag (NARDL) model was employed to scrutinize the asymmetrical impact of various transport modes on GDP. We used quarterly data from 2004–2021 for the Visegrad countries. In addition, a Toda-Yamamoto test was performed to establish causality between variables. The study found evidence of differing impacts of transport modes on economic growth in the examined countries. Specifically, international, and cross-trade transport had a balanced effect on GDP growth, whereas cabotage and domestic transport had an imbalanced impact. The Toda-Yamamoto method's causality analysis results demonstrate bidirectional causality between freight work and GDP in both international and domestic transportation for the Czech Republic, Poland, and Poland's cross-trade. On the other hand, unidirectional causality was established for cross-trade in Hungary, Slovakia, and the Czech Republic. Based on the conducted estimation, it was deduced that the impact of specific transport modes on economic growth is uneven and reliant on both the transport mode and the country. The significant results obtained hold critical implications for economic policy, enabling the adaptation of strategies and regulations to foster growth based on variances in the influence of road transportation on the economy.

Keywords: road transport, economic growth, NARDL, asymmetric effects, Toda-Yamamoto, causality

JEL classification: C01, C32, E01, R40

Introduction

The freight transport sector is essential to the functioning of any country's economy, facilitating the movement of production goods (Ali et al., 2018). As economies grow and evolve, the significance of a proficient road transport system becomes increasingly evident (Suproń & Łącka, 2020). The impact of transportation on the economy is extensive, encompassing numerous sectors (Krawczyk & Kokot-Stępień, 2020).

Road freight transport is essential for moving goods both domestically and internationally (Grzelakowski, 2018). It enables the efficient transport of raw materials, finished products, and other goods from production plants to distribution centres, retail shops, and final consumers (Pisa, 2019). This seamless flow of cargo is essential for a well-functioning supply chain and supports various industries.

The road freight industry is labour-intensive and a positive contributor to the labour market. It employs workers in many areas related to supply chains, generating income (Vigo, 2018). Road freight transport also facilitates national and international trade by connecting production centres to markets. Efficient transport systems help companies reach a wider customer base and access resources from different regions, promoting economic growth and competitiveness (Łącka & Suproń, 2021).

Road transport is also the free movement of goods between different regions, providing a more balanced distribution of resources and promoting economic integration (Gainsborough, 2012). Improved transport accessibility impacts investment and industry, leading to economic development and employment opportunities for local communities (Tarigan et al., 2021). The contribution of road freight transport to economic growth also includes the direct generation of value added by transport companies, as well as indirectly stimulating growth through its impact on other sectors of the economy (Limani, 2016).

The role of road transport is particularly important in the countries of the Visegrad Group (V4), which consists of Poland, Hungary, Slovakia, and the Czech Republic (Suproń & Łącka, 2023). The V4 group represents about one-tenth of the EU economy and has an average standard of living per capita above 70% of the EU standard (Galstyan, 2021). These countries share similar economic conditions and are also beneficiaries of the 2004 enlargement of the European Union. Accession to the European Union opened up the common European market for the V4 economies, resulting in dynamic economic growth and an influx of foreign direct investment (Lomachynska et al., 2020). At the same time, economic development has contributed to an increase in freight exchange, especially via road transport, which accounts for 75% of all freight transport (Eurostat, 2022). In the Visegrad countries themselves, it is also one of the most important economic sectors generating GDP (Varjan et al., 2017). In conclusion, therefore, road freight transport plays a key role in the economic development of the V4, contributing to increased production, job creation, and improved business competitiveness.

Road transport of goods in the European Union is categorised into several types with different impacts on economic growth, in legal terms. National transport refers to transport within a single national territory, while international transport refers to transport between multiple countries. In addition, cabotage transport refers to the transportation of goods within a country by a carrier from another country, while cross-trade transport involves the transportation of goods between two countries by a carrier from a third country. Clarification of technical abbreviations such as "cabotage" may be necessary.

The impact of the different modes of transport on the market and the economy has become particularly significant in recent years, especially following the introduction of the Mobility Package, the motive for which was to restrict the latter two modes. These measures were motivated by protectionism and the need to protect the markets of individual community countries (Suproń, 2020). With these considerations in mind, it made sense to examine how the different modes of transport interact with economic growth. Understanding the economic importance of different road transport modes is crucial for both policy makers and stakeholders. By identifying the economic impacts of each mode of transport, policy makers can develop targeted strategies, as well as adjust regulations to promote economic growth.

General studies of the interaction between GDP and road transport using econometric methods are scarce. Research work for Mexico has found that road transport and GDP have a cointegrating relationship. The relationship between freight turnover and GDP is linear, and the freight work required to unit GDP growth decreases as the economy grows (Berrones-Sanz, 2020). In contrast, a study conducted in China indicated that an increase in freight turnover and the number of transport companies leads to an increase in regional GDP (Wang et al., 2021). Studies of China's economy also revealed the existence of a stable, sustainable, and long-term relationship between road freight volumes, fuel oil prices, and the national economy(Ma et al., 2020). In contrast, another study looked at Kazakhstan and found that the causal relationship between transport freight turnover and GDP, depending on the region, could be one- or two-way (Taisarinova et al., 2020). A study for the European Union using the correlation method, on the other hand, confirmed that GDP growth also increases with an increase in freight work (Gnap et al., 2018). The analysis of the available sources thus indicates that the current state of econometric research covering the analysis of the relationship between economic growth and road freight transport is insufficient. Given the above, it has become reasonable to fill the research gap that exists.

Based on the available body of knowledge, this article aimed to investigate the impact of individual road transport modes on economic growth in the Visegrad countries. To achieve the stated objective, an innovative research approach was used involving the Nonlinear Autoregressive Distributed Lag (NARDL) methodology allowing for an asymmetric assessment of individual types of transport on GDP.

As there is currently a lack of studies in the national and international literature, especially those that use adapted econometric methods in the field of transport economics, such as the ARDL and NARDL models, this analysis goes beyond the available studies in several ways. Firstly, there is no well-established literature that examines both symmetric and asymmetric impacts of the mentioned transport modes on GDP, especially for the V4 countries. Secondly, this study uses both the NARDL model and causality analysis based on the Toda-Yamamoto method, which has not been applied to road freight transport so far, which is a contribution, especially in the field of transport economics.

The remainder of the study is designed as follows: the " Materials and methods " section presents the material and method. The section " Results and Analysis " discusses the results of the study. The "Conclusions" section provides concluding remarks and directions for future research. The "Completion", on the other hand, presents the policy implications arising from the research conducted.

2. Material and methods

2.1 Data

This paper examines the asymmetric relationship between economic growth, as measured by GDP per capita at 2015 constant prices, and freight transportation work in million tonne-kilometers: international (IN), national (N), cross-trade (CT), and cabotage (CB). Quarterly data covering the period between 2004 and 2021 were obtained from the Eurostat database. To counter seasonal effects, we incorporated dummy variables indicating the quarterly periods Q1, Q2, and Q3 into the model. The series was transformed to log-linear form to remove serial correlation and heteroskedasticity.

The estimation included the quarterly time series from Q1 2004 to Q4 2021, while the year 2022 was not considered due to the unavailability of Q4 2022 data during the study. The study features detailed descriptive statistics for the series studied, which are presented in Table 1.

Table 1. Descriptive statistics

Country	Variable	Mean	Median	Max	Min	Std. Dev.	n
Czech Republic	lnGDP	8,284	8,271	8,466	7,996	0,108	75
	lnCT	7,350	7,461	8,064	5,398	0,595	75
	lnCB	4,657	5,176	6,194	0,693	1,344	75
	lnIN	8,931	9,024	9,380	7,885	0,303	75
	lnN	8,442	8,390	9,147	7,804	0,307	75
Hungary	lnGDP	7,927	7,894	8,232	7,669	0,135	75
	lnCT	7,432	7,577	8,069	4,654	0,619	75
	lnCB	4,743	5,252	5,823	2,565	0,988	75
	lnIN	8,616	8,692	8,928	7,525	0,281	75
	lnN	7,978	7,990	8,301	7,571	0,179	75
Poland	lnGDP	7,845	7,832	8,276	7,444	0,207	75
	lnCT	9,041	9,125	10,000	6,731	0,718	75
	lnCB	7,163	7,483	8,805	4,382	1,294	75
	lnIN	10,039	10,091	10,542	9,423	0,289	75
	lnN	10,401	10,499	11,119	9,274	0,515	75
Slovak Republic	lnGDP	8,105	8,126	8,355	7,673	0,167	75
	lnCT	7,774	7,896	8,303	6,736	0,318	75
	lnCB	4,909	5,313	6,068	1,946	1,029	75
	lnIN	8,675	8,725	9,034	7,941	0,222	75
	lnN	7,244	7,271	7,516	6,693	0,177	75

Source: own elaboration

2.2 Methodology

The methodology used in the study is based on the estimation of the NARDL model. This model is an econometric model used to analyse long- and short-run relationships between variables in time series (Rajput et al., 2019). The model allows for both asymmetric and non-linear effects of the independent variables on the dependent variable, which makes it particularly useful for studying economic phenomena that often exhibit non-linearity or asymmetry. The NARDL model is an extension of the ARDL model, which allows for the possibility of non-linear effects in the short run but assumes linearity in the long run. In contrast, the NARDL model allows for non-linearity in both short- and long-term relationships between variables (Pesaran et al., 2001). Like the standard ARDL model, NARDL helps explain the relationship in the presence of both I(0) and I(1) integrated variables and provides efficient and reliable results with a relatively small sample size (Nkoro & Uko, 2016).

The application of the NARDL model requires testing the stationarity of the time series. This is due to theoretical implications, as ARDL class models can only be estimated for integrated variables at the I(0) or I(1) level, while their estimation is not valid for I(2) variables (Pesaran & Shin, 1999). To test for stationarity in the study, the Im, Pesaran, and Shin IPS tests were used (Im et al., 2003).

In the NARDL model, asymmetry means that the effects of positive and negative changes in the independent variable may not be the same. This means that the relationship between the independent variable and the dependent variable may be different when the independent variable increases and different when it decreases (Hatemi-J, 2012). Asymmetry may be due to various reasons, such as market distortions, institutional factors, or behavioural factors.

In the NARDL model, there is a subtotal decomposition of the distribution of lagged variables. The positive and negative variances of the explanatory variable X_t are decomposed, such that X_t^+ i X_t^- represent its positive and negative effects on the explanatory variable. The analytical form of the equation is expressed as follows (Shin et al., 2014):

(1)

$$X_t = X_0 + X_t^+ + X_t^-$$
$$X_t^+ = \sum_{s=1}^{t} \max(\Delta X_s, 0)$$
$$X_t^- = \sum_{s=1}^{t} \min(\Delta X_s, 0)$$

The concept of the NARDL model is derived from the non-linear ARDL model proposed by Y. Shin and takes the general form (Shin et al., 2014):

(2)

$$yt = \sum_{i=1}^{p} \lambda_i y_{t-i} + \sum_{i=0}^{q} (\delta_j^{+'} x_{t-i}^{+} + \delta_{t-i}^{-'} x_{t-i}^{-}) + \varepsilon t$$

Where:
Short-term relationship parameters with asymmetry components: $\lambda_{i,} \delta^+, \delta^-$
Long-term relationship parameters with asymmetry components: $\rho, \varphi^+, \varphi^-$
εt *is a random variable.*

Based on the general form of the NARDL model, the following model was used in the study:

(3)

$$\Delta Yt = \beta_0 + \sum_{i=1}^{p=1} \lambda_i \Delta Y_{t-i} + \sum_{i=0}^{q} \delta_i^+ \Delta X_{t-i}^+ + \sum_{i=0}^{q} \delta_i^- \Delta X_{t-i}^- + \rho Y_{t-1} + \varphi^+ X_{t-1}^+ + \varphi^- X_{t-1}^- + \varepsilon_t$$

Asymmetry and cointegration testing were carried out based on the Wald test for the following conditions:

– For the short term $\sum_{i=1}^{Q} \delta_i^- = \sum_{i=1}^{Q} \delta_i^+ \ lub \ \delta_i^- = \delta_i^+$
– For the long term $\varphi^- = \varphi^+$

All the obtained models were subjected to diagnostic tests to confirm the correctness of the estimation and the fit to the methodological framework. Diagnostics included the following tests: serial correlation tests - LM test (Breusch, 1978), and heteroskedasticity - ARCH test (Engle, 1982). In addition, stability was examined graphically using the measured cumulative sum - CUSUM (Brown et al., 1975).

In the final stage of the study, causality tests for individual data were conducted based on the Toda-Yamamoto test (Toda & Yamamoto, 1995). The TY method is carried out in two stages using the S-VAR model. First, the optimal lag length (k) and the maximum order of integration (dmax) are determined, and then the VAR model is estimated at the series level. In addition, it is tested whether the VAR (k + dmax) has been determined correctly. The second step uses a modified Wald procedure to test the VAR (k) model for causality by determining whether the optimal lag length is equal to p = [k + d (max)]. Based on the results, causality between pairs of variables was determined, indicating whether it is a unidirectional, bidirectional, or cause-and-effect relationship.

To graphically illustrate the impact of modal shifts on economic growth in the form of shocks, cumulative dynamic multipliers have been plotted based on the NARDL methodology (Shin et al., 2014).

3. Results and analyses

3.1 Long and short-term model estimates

According to the methodology, the application of the NARDL analytical framework requires time series to be stationary at I (0), I (1), or mixed levels. Stationarity tests were carried out using IPS unit root tests. Table 2 shows the results, which indicate that all variables are stationary at the first difference. The methodological assumptions for the application of the ARDL/NARDL methodology have therefore been met for the variables under consideration.

Table 2. IPS-ADF unit root tests

Country	Series	Level		First difference		Result
		t-Stat	Prob.	t-Stat	Prob.	
Czech Republic	lnGDP	-1,371	0,592	-3,022	0,038	I (1)
	lnCT	-2,293	0,177	-10,862	0,000	I (1)
	lnCB	-2,344	0,161	-8,038	0,000	I (1)
	lnIN	-2,327	0,167	-10,908	0,000	I (1)
	lnN	0,110	0,964	-4,794	0,000	I (1)
Hungary	lnGDP	0,413	0,982	-1,618	0,468	I (1)
	lnCT	-2,434	0,136	-4,598	0,000	I (1)
	lnCB	-1,524	0,516	-12,946	0,000	I (1)
	lnIN	-3,322	0,018	-3,636	0,007	I (0)/I (1)
	lnN	-3,848	0,004	-3,010	0,039	I (0)/I (1)
Poland	lnGDP	-0,572	0,869	-5,457	0,000	I (1)
	lnCT	-4,032	0,002	-6,320	0,000	I (0)/I (1)
	lnCB	-1,976	0,297	-10,444	0,000	I (1)
	lnIN	-3,565	0,009	-8,440	0,000	I (0)/I (1)
	lnN	-0,161	0,938	-15,432	0,000	I (1)
Slovak Republic	lnGDP	-2,976	0,042	-2,918	0,049	I (0)/I (1)
	lnCT	-4,429	0,001	-9,080	0,000	I (0)/I (1)
	lnCB	-2,269	0,185	-10,286	0,000	I (1)
	lnIN	-3,902	0,003	-9,344	0,000	I (0)/I (1)
	lnN	-1,485	0,535	-2,564	0,096	I (1)

Source: own elaboration

The BDS test - Brock, Dechert, Scheinkman, and LeBaron test of independence - was used to detect non-linearity in the time series studied. (Broock et al., 1996). The results of this test are presented in Table 3. The data obtained show that for all the time series we can reject hypothesis H0, which assumes that the time series are generated by a linear stochastic process. Given the above, both the results of the unit root test and the BDS test indicate that the time series under consideration allow the application of the NARDL model.

Table 3 The BDS test of independence

Country	Series	D2	D3	D4	D5	D6
Czech Republic	lnGDP	0,151*	0,277*	0,369*	0,434*	0,476*
	lnCT	0,134*	0,220*	0,279*	0,326*	0,350*
	lnCB	0,001*	-0,017*	-0,028*	0,016*	0,043*
	lnIN	0,151*	0,277*	0,369*	0,434*	0,476*
	lnN	0,134*	0,220*	0,279*	0,326*	0,350*
Hungary	lnGDP	0,001**	-0,017**	-0,028**	0,016**	0,043**
	lnCT	0,151*	0,277*	0,369*	0,434*	0,476*
	lnCB	0,134*	0,220*	0,279*	0,326*	0,350*
	lnIN	0,001*	-0,017*	-0,028*	0,016*	0,043*
	lnN	0,151*	0,277*	0,369*	0,434*	0,476*
Poland	lnGDP	0,134*	0,220*	0,279*	0,326*	0,350*
	lnCT	0,001*	-0,017*	-0,028*	0,016*	0,043*
	lnCB	0,151*	0,277*	0,369*	0,434*	0,476*
	lnIN	0,134*	0,220*	0,279*	0,326*	0,350*
	lnN	0,001*	-0,017*	-0,028*	0,016*	0,043*
Slovakia	lnGDP	0,151*	0,277*	0,369*	0,434*	0,476*
	lnCT	0,134*	0,220*	0,279*	0,326*	0,350*
	lnCB	0,001*	-0,017*	-0,028*	0,016*	0,043*
	lnIN	0,151*	0,277*	0,369*	0,434*	0,476*
	lnN	0,134*	0,220*	0,279*	0,326*	0,350*

Note: *, **, *** indicate significance at the 1%, 5%, and 10% levels, respectively
Source: Own elaboration

An examination of the significance of asymmetry for the variables and models tested is presented in Table 4. The estimation of the presence of asymmetry was developed based on Wald tests. The results confirm the existence of long-term asymmetry for the variable lnCT for the Hungarian model. For the variable lnCB, long-run asymmetry was found for the Czech Republic and the Polish model, and lnIN for Hungary, Poland, and the Czech Republic. For the last variable tested N, asymmetry was found for the Czech Republic, Hungary, and Slovakia. At the same time, based on the Wald test, no significant short-run asymmetry was found for the tested models.

Table 4. Wald asymmetry test with $\chi 2$ statistic

Country	lnCT	lnCB	lnIN	lnN
Czech Republic		6,493*		6,279**

Hungary	20,929*		18,036*	2,852***
Poland		9,686*	19,139*	
Slovak Republic			11,483*	6,475*

Note: *, **, *** indicate significance at the 1%, 5%, and 10% levels, respectively
Source: Own elaboration

A non-linear frontier test was carried out to establish cointegration, which allows us to infer the long-run relationship in the model under study. The results of this test are shown in Table 5. The values of the F-statistic for all the countries studied are greater than I (1) at the 1% significance level, indicating the existence of a non-linear long-run relationship between the variables.

Table 5. NARDL boundary test results

Country	Value of F-statistics	Level of significance	Lower bound I (0)	Upper bound I (1)
Czech Republic	10,720*	10%	2.100	3.121
		5%	2.451	3.559
		1%	3.180	4.596
Hungary	5,474*	10%	2.631	3.589
		5%	3.043	4.100
		1%	3.966	5.234
Poland	9,386*	10%	2.100	3.121
		5%	2.451	3.559
		1%	3.180	4.596
Slovak Republic	7,208*	10%	2.103	3.111
		5%	2.449	3.550
		1%	3.219	4.526

Note: *, **, *** indicate significance at the 1%, 5%, and 10% levels, respectively
Source: Own elaboration

Due to the evidence of cointegration, a long-run model was estimated for the countries under study, the results of which are presented in Table 6. According to the results of the long-run estimates for the Czech Republic, cabotage and national transport have an asymmetric effect on economic growth, while international and cross-trade transport have a symmetric effect. In the long run, a 1% increase in cross-trade transport reduces GDP by 0.16%, while a 1% increase in international transport reduces GDP growth by 0.02%.

The coefficients of the asymmetric variables for cabotage indicate that a 1% increase in cabotage transport generates a 0.02% increase in GDP, while a decrease in cabotage transport generates a 0.01% increase in GDP. In the case of national transport, a 1% increase in cabotage leads to a 0.19% increase in GDP, while a decrease affects GDP by 0.24%.

For the Hungarian model, a 1% increase in international freight transport work leads to a 0.64% increase in GDP in the long run, while an increase in cross-trade freight transport work leads to a 0.35% decrease in GDP. For international transport, a negative change was significant, resulting in a 0.11% increase in GDP.

A test of the model coefficients for Poland indicates that domestic transport has a symmetrical effect on GDP in the long run. According to the estimated parameters, a 1% increase in transport work leads to a 0.88% increase in GDP. An asymmetric effect was found in the case of cabotage transport, where an increase in transport work leads to a decrease in GDP of 0.17% in the long run.

The last country analysed was Slovakia, where two statistically significant asymmetric effects were confirmed. There is a negative effect for national freight transport, where a 1% decrease in transport work leads to a 0.1% decrease in GDP, and for international freight transport, where an increase in transport work leads to a 0.47% increase in GDP in the long run.

Table 6. Results of NARDL long-run model estimation

Country	Variables	Co-efficient	Std. Error	t-statistics	Prob.
Czech Republic	$lnCT_{t-1}$	-0,164	0,072	-2,287	0,026
	$lnIN_t$	0,194	0,116	1,668	0,090
	φ^+ $lnCB_t$	0,019	0,010	1,858	0,068
	φ^- $lnCB_t$	-0,009	0,013	-0,745	0,459
	φ^+ lnN_{t-1}	0,187	0,053	3,526	0,001
	φ^- lnN_{t-1}	0,239	0,059	4,040	0,000
	Const	7,696	0,505	15,230	0,000
Hungary	$lnCB_t$	-0,019	0,021	-0,893	0,376
	φ^+ IN_{t-1}	0,650	0,162	4,024	0,000
	φ^- IN_{t-1}	0,189	0,138	1,365	0,177
	φ^+ $lnCT_t$	-0,355	0,087	-4,066	0,000
	φ^- $lnCT_t$	0,066	0,096	0,684	0,496
	φ^+ lnN_t	-0,028	0,053	-0,528	0,599
	φ^- lnN_t	-0,107	0,060	-1,779	0,080
	Const	0,187	0,080	2,347	0,022
Poland	lnN_{t-1}	0,883	0,513	1,722	0,090
	$lnCT_{t-1}$	0,046	0,124	0,368	0,714
	$\varphi^+ lnIN_{t-1}$	0,293	0,252	1,163	0,250
	φ^- $lnIN_{t-1}$	-0,284	0,234	-1,212	0,230
	φ^+ $lnCB_t$	-0,171	0,080	-2,141	0,036
	φ^- $lnCB_t$	0,118	0,116	1,024	0,310
	Const	-1,636	5,281	-0,310	0,758
Slovak Republic	$lnCT_t$	-0,042	0,074	-0,569	0,572
	$lnCB_t$	0,015	0,020	0,731	0,467
	φ^+ lnN_t	0,001	0,064	0,010	0,992
	φ^- lnN_t	0,099	0,057	1,743	0,086
	φ^+ $lnIN_t$	0,467	0,128	3,633	0,001
	φ^- $lnIN_t$	0,194	0,130	1,496	0,140
	Const	7,938	0,490	16,215	0,000

Source: own elaboration

Table 7 shows the short-run estimates for the countries examined. According to the estimated asymmetry Wald tests, there was no asymmetry in the short run. Therefore, only symmetric short-run coefficients were estimated. For all countries examined, the ECT coefficients are between 0 and -1 and are statistically significant. This result indicates that the long-run relationships revealed by the cointegration test are correct. At the same time, the obtained ECT coefficient result indicates the speed of adjustment of the long-run equilibrium in case of the occurrence of short-run shocks. The coefficient ranges from -0.24 for Poland to -0.53 for Hungary. This means that the return to the long-run equilibrium in the countries under examination is relatively fast in the event of changes in the variables under examination, ranging from 2 to 4 quarters.

Table 7. results of NARDL short-term model estimation

Country	Variables	Co-efficient	Std. Error	t-statistics	Prob.
Czech Republic	ECT_{t-1}	-0,345	0,035	-9,864	0,000
	ΔCT_t	-0,052	0,007	-7,252	0,000
	ΔCT_{t-1}	0,005	0,006	0,795	0,430
	ΔCT_{t-2}	-0,024	0,006	-4,352	0,000
	ΔN_t	0,066	0,018	3,741	0,000
	ΔN_{t-1}	-0,028	0,019	-1,530	0,131
	ΔN_{t-2}	-0,072	0,015	-4,970	0,000
	Q1	-0,108	0,007	-15,176	0,000
	Q2	-0,013	0,011	-1,252	0,216
	Q3	-0,050	0,009	-5,431	0,000
Poland	ECT_{t-1}	-0,248	0,027	-9,230	0,000
	ΔGDP_{t-1}	-0,256	0,084	-3,049	0,003
	ΔN_t	0,103	0,028	3,723	0,000
	ΔN_{t-1}	-0,129	0,035	-3,674	0,001
	ΔN_{t-2}	-0,089	0,028	-3,174	0,002
	ΔCT_t	-0,047	0,023	-2,028	0,047
	ΔIN_t	0,097	0,038	2,539	0,014
	Q1	0,051	0,019	2,714	0,009
	Q2	0,102	0,009	11,181	0,000
	Q3	0,218	0,009	23,617	0,000
Hungary	ECT_{t-1}	-0.535	0.112	-4.772	0.000
	ΔIN_t	0,299	0,061	4,903	0,000
	ΔIN_{t-1}	-0,039	0,030	-1,331	0,189
	Q1	-0,203	0,011	-18,039	0,000
	Q2	-0,030	0,015	-2,026	0,048
	Q3	-0,031	0,008	-3,803	0,000
Slovak Republic	ECT_{t-1}	-0,351	0,044	-8,024	0,000
	Q1	-0,091	0,004	-22,409	0,000
	Q2	0,046	0,006	7,550	0,000
	Q3	0,054	0,004	13,630	0,000

Source: own elaboration

All short-run coefficients for the variables included in the models are significant and indicate the extent of the 1% change in GDP for the countries studied. The main direction of the positive effect on GDP in the countries studied is an increase in freight work, in the short term in domestic and international transport, with a negative effect on cabotage and cross-trade. The dummy variables used in the seasonal effect models also indicate that the dependent variable is under the influence of seasonal fluctuations in the independent variables. The graphical impact of shocks resulting from changes in the independent variables on the dependent variable is presented in the form of cumulative plots of dynamic multipliers in Appendix 1.

3.2 Diagnostics tests of the estimated models

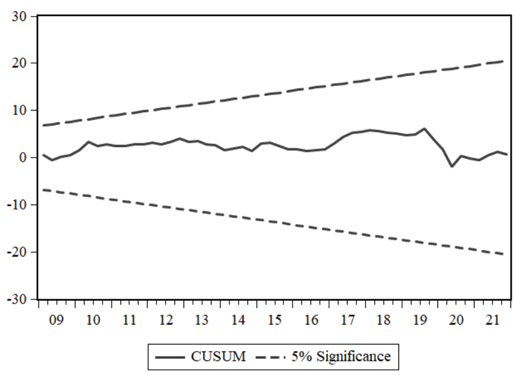
Diagnostic tests were carried out to confirm the robustness and validity of the estimated models. The results are presented in Table 8. For all the tests carried out, the probabilities are greater than 0.05, which confirms the absence of bias in the estimated models and also indicates that they are legitimately specified. The high R2 values and the rejection of the H0 hypothesis in the Ramsey test also indicate that the dependent variables were well chosen and explain the dependent variable under study.

CUSUM plots (Figure 1) were used to test the stability of the estimation models. The recursive residuals are within the critical value of 5%, as shown in the plots of the results CUSUM test. Such a result suggests that the models are stable.

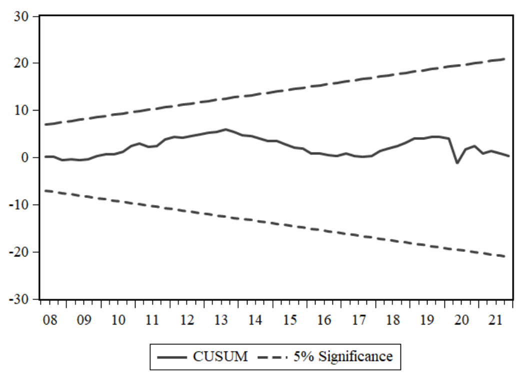
Table 8. Diagnostic tests of the estimated models

Test		Czech Republic	Poland	Hungary	Slovak
Heteroskedasticity ARCH	F-statistics	0,720	0,854	0,282	0,127
	Prob.	0,399	0,359	0,597	0,722
LM Test	F-statistics	0,135	0,928	0,755	0,563
	Prob.	0,874	0,402	0,475	0,573
Ramsey (RESET)	F-statistics	2,051	2,534	2,219	0,271
	Prob.	0,158	0,118	0,119	0,605
Durbin-Watson			2,059	1,931	1,802
R-squared			0,964	0,981	0,971

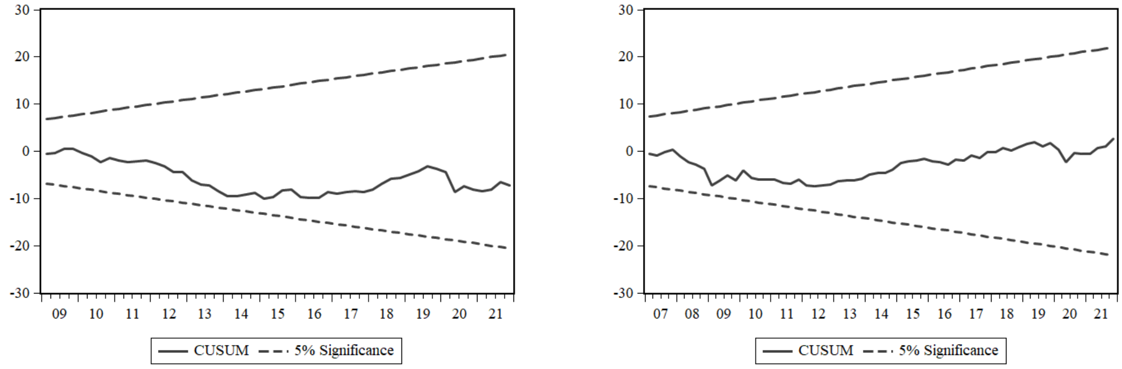
Source: own elaboration



Czech Republic



Hungary



Poland Slovak Republic

Figure 1. CUSUM diagrams for the models studied.

Source: own elaboration.

3.3 Causality testing based on the Toda-Yamamoto method

In the final stage of the study, causality tests based on the Toda-Yamamoto methodology were conducted to determine the directions of influence of the study variables. The results, presented in Table 9, revealed several causal relationships between the study variables. In all the countries studied, there was a bi-directional causality between international transport work and GDP [IN←→GDP]. In the Czech Republic and Poland, there was also a bidirectional causality between national transport freight work and GDP [NT←→GDP]. For Poland, a bidirectional causality was also found between freight work in cross-trade transport and GDP [CT←→GDP].

Unidirectional causality was found between cross-trade transport work and GDP for the Czech Republic [CT→GDP] and Hungary and Slovakia [GDP→CT]. For Hungary, unidirectional causality was also confirmed between national transport and GDP [N→GDP]. At the same time, the results did not confirm causality between cabotage transport and GDP [CB≠GDP] for any of the countries studied.

Table 9. Results of Toda-Yamamoto causality tests

Cause → Effect	Czech Republic		Poland		Hungary		Slovak Republic	
	χ2	p-value	χ2	p-value	χ2	p-value	χ2	p-value
lnGDP → lnCT	1,435	0,488	19,655	0,000	8,787	0,067	4,199	0,040
lnCT → lnGDP	11,430	0,003	5,268	0,022	5,240	0,264	0,145	0,703
lnGDP → lnCB	0,617	0,734	2,214	0,137	8,788	0,067	0,055	0,815
lnCB → lnGDP	3,778	0,151	0,837	0,360	5,998	0,199	0,000	0,983
lnGDP → lnIN	5,835	0,054	17,630	0,000	17,430	0,002	2,859	0,091
lnIN → lnGDP	10,971	0,004	3,912	0,048	10,010	0,040	6,117	0,013
lnGDP → lnN	16,428	0,000	5,973	0,015	5,886	0,208	0,003	0,960
lnN → lnGDP	9,785	0,008	15,013	0,000	11,053	0,026	0,084	0,772

Source: own elaboration

4. Conclusions

The main objective of the study was to assess, using empirical methods, the impact of the different modes of road transport on the economies of the V4 countries. The application of the NARDL model made it possible to determine the impact of both positive and negative shocks related to changes in freight work on GDP. The findings made it possible to conclude that in all Visegrad countries, road transport plays a very important role in economic development.

The study showed that transport work in national and international transport has a positive impact on GDP in the Czech Republic, Hungary, Poland, and Slovakia. In the Czech Republic, cabotage transport work also has a positive effect on GDP, but less than for national and international transport. In Poland and Hungary, cabotage transport work has a negative effect on GDP. The results obtained at the same time confirm the existence of asymmetric effects in the long term along the line of the relationship between freight work and economic growth. It is worth pointing out that most of the variables studied showed a greater impact on GDP when they increased than when they decreased. This indicates that positive shocks play a much greater role, whereas when negative shifts occur, recovery is relatively quick. Short-term observations, on the other hand, suggest that the impact of the surveyed variables on economic growth is relatively dynamic in all V4 countries.

Finally, causality analysis suggests that there is a feedback loop in the V4 countries between international transport and economic growth. The V4 countries are highly economically integrated and international transport enables the movement of goods and services between them. Increased trade leads to economic growth, and economic growth leads to increased demand for international transport. In addition, V4 countries are important producers for European companies, and international transport enables the delivery of raw materials and components to factories, as well as the delivery of finished products to consumers. Industrial growth leads to economic growth, and economic growth leads to increased demand for international transport.

In the case of Poland and the Czech Republic, there is also a feedback loop between domestic transport and economic growth. This result can be explained by the fact that Poland and the Czech Republic have larger economies than Hungary and Slovakia. This means that domestic transport plays a greater role in the flow of goods and services and the delivery of goods to consumers. Again, the larger internal market to which domestic products are supplied plays an important role. At the same time, it should be noted that due to the lack of research using dynamic econometric models in this area, the results cannot be compared with other work.

Completion

Overall, the findings of the study suggest that road transport is a pivotal element of the V4 countries' economy. Nurturing the evolution of road transport can escalate the prospects of economic growth for V4 countries. Nevertheless, it is crucial to acknowledge that road transport also harbours certain ecological and societal hazards, which are especially pertinent in the current period of energy progression. In conclusion, numerous policy implications can be deduced from the results obtained.

Firstly, V4 countries should promote the advancement of road transport. This can involve investments in road infrastructure, tax exemptions for transport companies, and facilitating international freight transport. It is also important to safeguard the sector from the impacts of the energy transition. Furthermore, the V4 countries should collaborate on transport policy. This could involve coordinating investment in road infrastructure, jointly lobbying for the shaping of favourable transport legislation, and making joint efforts to improve road safety. By promoting the development of road transport, V4 countries can increase their chances of economic growth.

Lastly, V4 nations should safeguard their transport industry against competition from foreign haulage companies. This could involve securing the market by applying the provisions of the Mobility Package, particularly in the areas of cabotage and cross-trade. It could also entail exerting greater influence on the European Union authorities to impose constraints on third-country hauliers operating in domestic market areas.

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ASYMETRYCZNY WPŁYW RÓŻNYCH RODZAJÓW TRANSPORTU DROGOWEGO NA WZROST GOSPODARCZY W KRAJACH WYSZEHRADZKICH: ANALIZA EMPIRYCZNA PRZY WYKORZYSTANIU MODELU NARDL

Streszczenie

Współczesna gospodarka polega na efektywnej infrastrukturze transportowej, a transport drogowy towarów odgrywa kluczową rolę w dynamicznym wzroście gospodarczym i handlu. Celem artykułu było zbadanie wpływu poszczególnych rodzajów transportu drogowego na wzrost gospodarczy w krajach Grupy Wyszehradzkiej. W artykule zastosowano model nieliniowego autoregresyjnego rozproszonego opóźnienia (NARDL), aby zbadać asymetryczne oddziaływanie różnych rodzajów transportu na PKB. Badanie wykorzystuje dane kwartalne z lat 2004-2021. Dodatkowo w celu potwierdzenia uzyskanych obserwacji przeprowadzono badanie przyczynowości pomiędzy zmiennymi przy pomocy metody Toda-Yamamoto. Uzyskane wyniki wykazały, że istnieje zarówno symetryczny, jak i asymetryczny wpływ poszczególnych rodzajów transportu na wzrost gospodarczy w badanych krajach. Przewozy międzynarodowe i cross-trade oddziałują symetrycznie na wzrost PKB, natomiast przewozy kabotażowe i krajowe oddziałują asymetrycznie. Wyniki analizy przyczynowości opartej na metodzie Toda-Yamamoto wskazały dwukierunkową przyczynowość pomiędzy pracą przewozową a PKB w transporcie międzynarodowym i krajowym dla Czech i Polski, a także przewozami typu cross-trade dla Polski. Przyczynowość jednokierunkowa została potwierdzona dla przewozów cross-trade w przypadku Czech, Węgier i Słowacji. Na podstawie przeprowadzonej estymacji stwierdzono, że wpływ poszczególnych rodzajów transportu na wzrost gospodarczy jest asymetryczny i zależy od rodzaju przewozów oraz aspektów regionalnych Osiągnięte wyniki mają istotne implikacje dla polityki gospodarczej, umożliwiając dostosowywanie strategii i przepisów w celu wspierania wzrostu gospodarczego na podstawie różnic w oddziaływaniu transportu drogowego na gospodarkę.

Słowa kluczowe: transport drogowy, wzrost gospodarczy, NARDL, efekty asymetryczne, Toda-Yamamoto, przyczynowość

Klasyfikacja JEL: C01, C32, E01, R40

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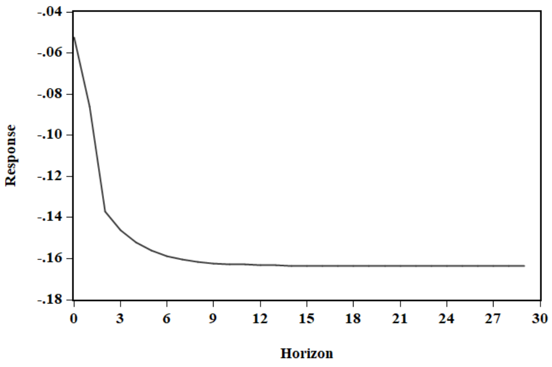
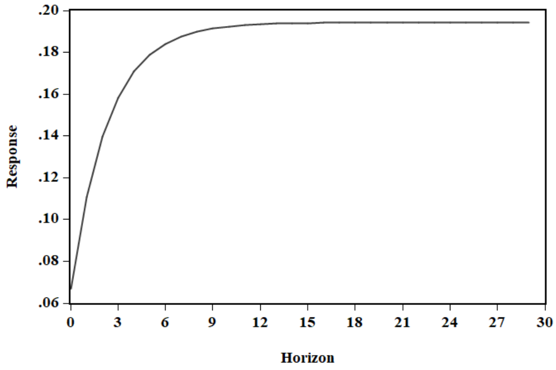
Annex 1. Cumulative multiplier charts - shock evolution

Czech Republic

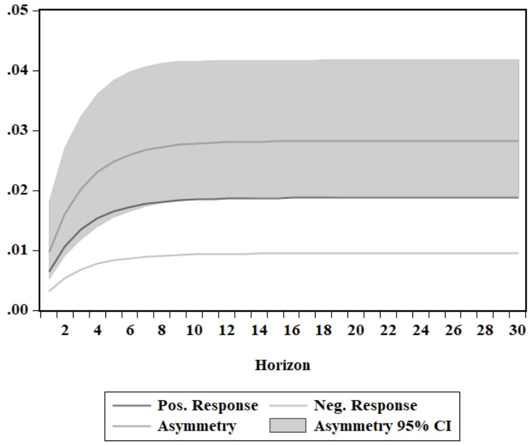
Cumulative Dynamic Multiplier: lnCT on lnGDP
Shock Evolution



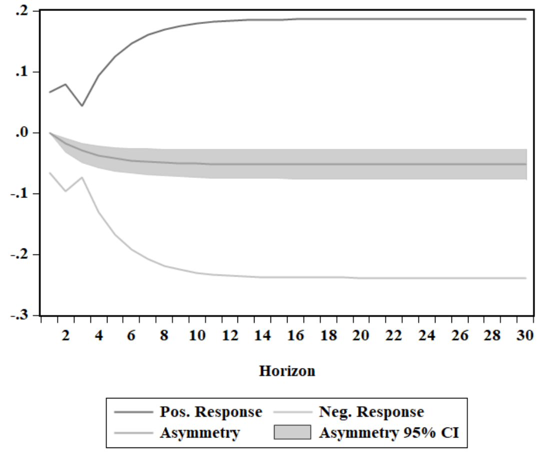
Cumulative Dynamic Multiplier: lnIN on lnGDP
Shock Evolution



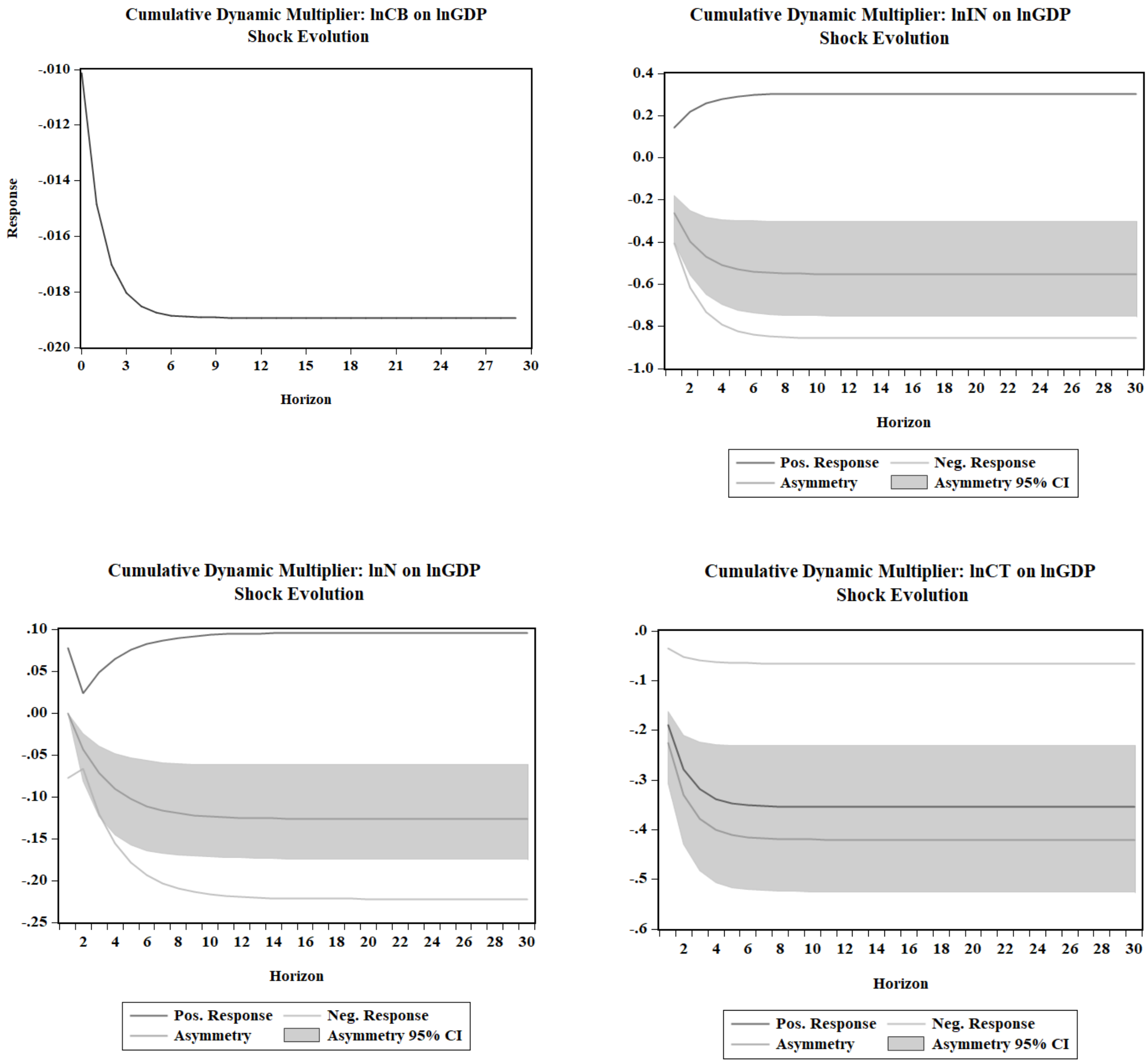
Cumulative Dynamic Multiplier: lnCB on lnGDP
Shock Evolution



Cumulative Dynamic Multiplier: lnN on lnGDP
Shock Evolution



Hungary


Cumulative Dynamic Multiplier: lnCB on lnGDP
Shock Evolution
Response
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Cumulative Dynamic Multiplier: lnIN on lnGDP
Shock Evolution
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Asymmetry
Asymmetry 95% CI
Cumulative Dynamic Multiplier: lnN on lnGDP
Shock Evolution
Horizon
Pos. Response
Neg. Response
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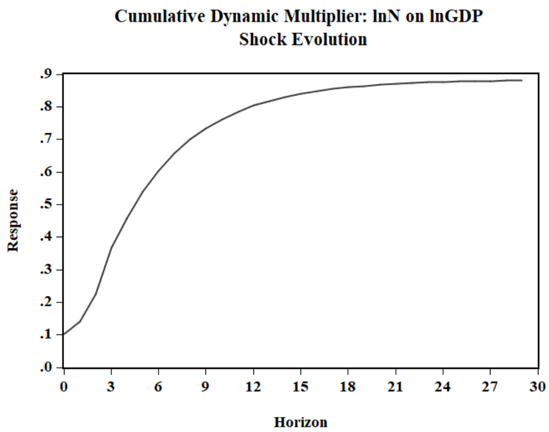
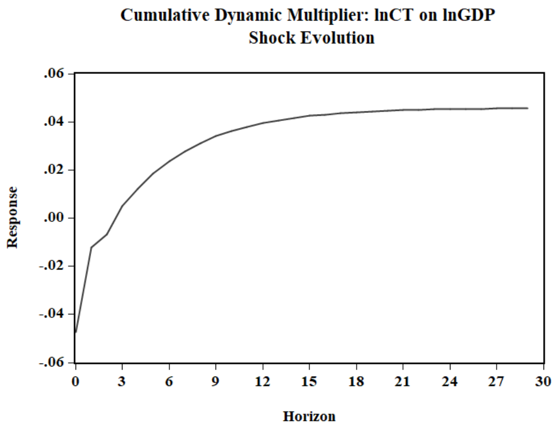
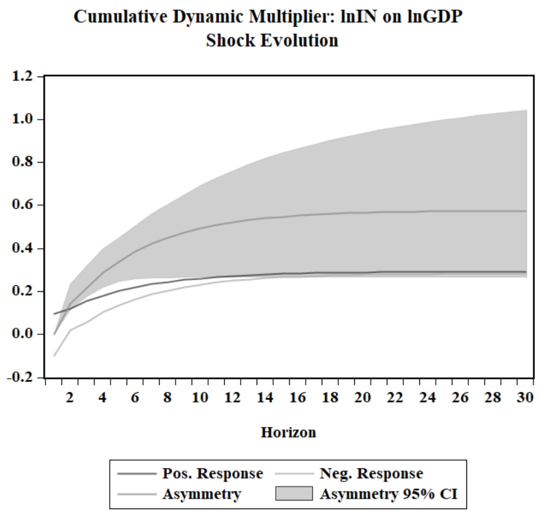
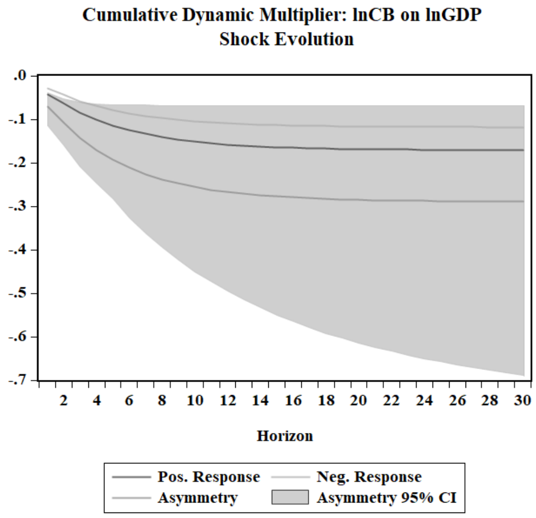
Asymmetry
Asymmetry 95% CI

Poland

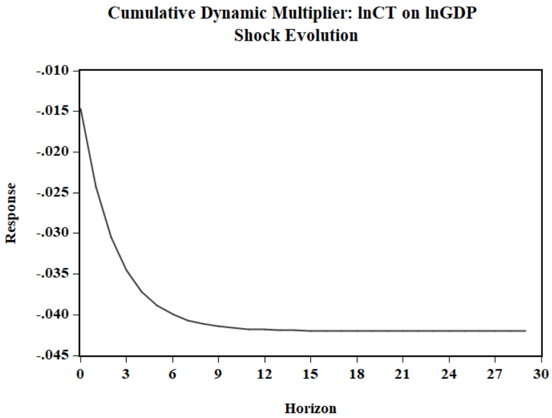


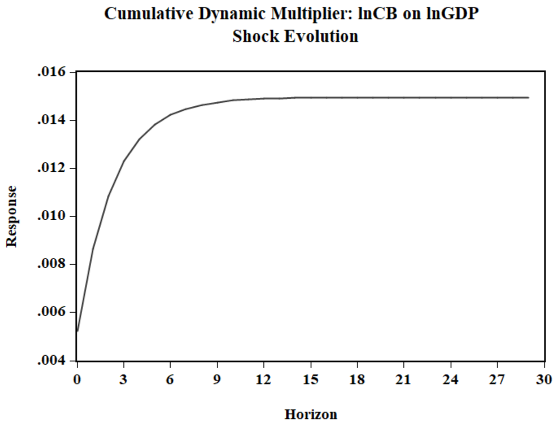


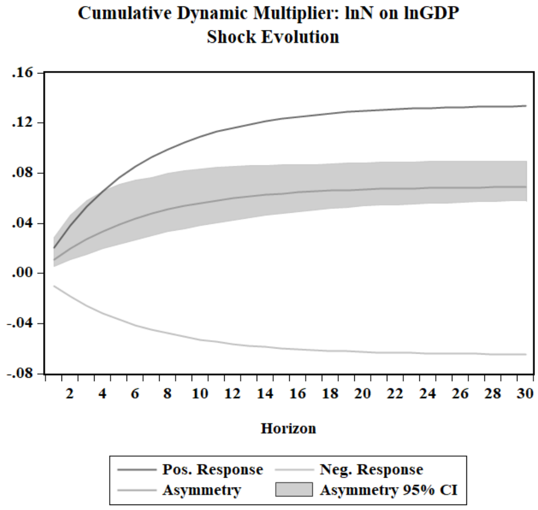




Slovak Republic






Cumulative Dynamic Multiplier: lnN on lnGDP
Shock Evolution
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.08
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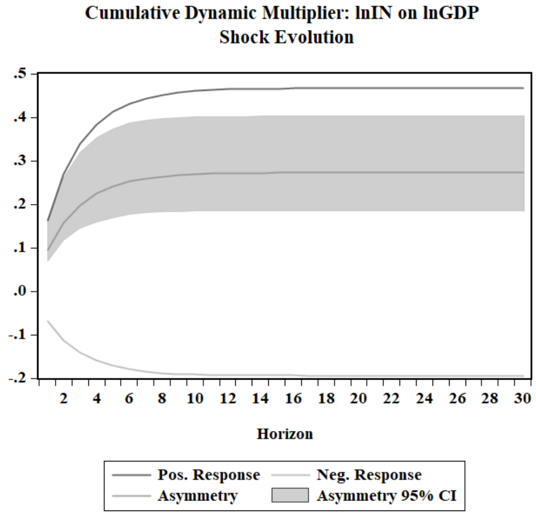
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Horizon
Pos. Response
Neg. Response
Asymmetry
Asymmetry 95% CI


Cumulative Dynamic Multiplier: lnIN on lnGDP
Shock Evolution
.5
.4
.3
.2
.1
.0
-.1
-.2
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Horizon
Pos. Response
Neg. Response
Asymmetry
Asymmetry 95% CI