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Development of Road Transport Logistic Infrastructure and Air Pollution in the Visegrad Group Countries

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Abstract

Road transport is a dominant branch of transport in majority of European countries, particularly in case of freight. Its common application results from availability of transport infrastructure and lower costs compared to other branches of transport. Unfortunately, road transport poses a serious threat to the natural environment due to emission of air pollution and noise. The research has shown that modern logistic transport infrastructure may significantly decrease the pression of transport on the environment. For this reason, the goal of this paper is to determine the level of a dynamic impact of transport infrastructure development on emission of pollution into the air, being a by-product of conventional fuels combustion in road transport in the Visegrad Group countries. The Granger causality relationship between road transport energy consumption, length of roads, number of cars and nitrogen oxides (NOx) emissions derived from road transport activity has been investigated for the Visegrad Group countries in the period of 1991-2015. Moreover, the response of the NO_x emissions to changes in road transport infrastructure and energy consumption have also been examined using the impulse response functions and variance decomposition of prediction error in the framework of the vector autoregression models (VAR) methodology.

Keywords: Road transport, logistic infrastructure, air pollution, VAR, impulse response function

Introduction

Transport constitutes an important part of the logistics concept, as it directly contributes to implementation of its primary goal, which is supplying a particular product to a particular place and in specific time. The share of freight in total transport is growing, therefore freight itself as well as efficiency of logistic services in the process of shipping goods is of vital importance for economic development. Thus, numerous references can be indicated between transport and logistics, which justifies its analysis in different dimensions, including the context of natural environment protection and transport infrastructure. Noise and air pollution are the most serious problems connected with transport [22]. In the literature on the subject one can find numerous analyses connected with the impact of road transport on carbon dioxide and greenhouse gases emission [26; 19; 20; 8]. Solutions aimed at limiting the transport emission are indispensable, despite the fact that they are much more expensive than in case of other economic sectors [21]. It has been proved that development of modern infrastructure is reflected in the reduced impact of transport on the natural environment, and reduction of pollutants emission in particular. Therefore, the aim of the present paper is to determine the level of dynamic impact of transport infrastructure development on nitrogen oxides emission in the Visegrad Group countries.

Logistic Infrastructure of Road Transport and its Influence on the Natural Environment

Logistics is a dynamically developing discipline, and its primary goal is to create efficient, effective flows of all types of resources. Carrying out the processes of transportation requires being equipped with proper infrastructure. Due to the fact that the infrastructure supports implementation of logistic processes it is called logistic infrastructure. Infrastructure is the core element for countries and regions development. Both the quality as well as the quantity of infrastructure is of vital importance for economic activity and its efficiency. Logistic infrastructure is considered to be an important factor that increases region competitiveness on the international market [3]. Co-operation and regional integration are particularly facilitated by transport infrastructure [28]. This infrastructure positively influences development of connections among regions and countries, thus it supports creation of mutual economic, social and cultural relations [23; 14; 2; 10; 11; 12]. The notion of transport infrastructure is understood as a functional and service subsystem which in the reproduction process influences the activity of behaviour of the subjects of its economic system ensuring combination of their interests with the integrated development tasks and it can be considered as rather independent system with its own objectives [18]. From the perspective of Logistics transport infrastructure should ensure efficiency of flow and reduce cost of transport. Thanks to flow efficiency a product is delivered in proper time to a proper place, according to the requirements of the supplier or the recipient. Costs of transport in turn influence the efficiency of system functioning and depend on the type of the applied transport itself as well as the specific means of transport, chosen routes and time of transport. Due to this fact the logistic infrastructure of transport is understood as a complex system of elements that support physical flows, the basic goal of which is ensuring social and economic development, and also effective execution of needs of all types of logistics and transport entities and improving warehousing processes [6]. The quality of trade- and transport-related infrastructure is one of the elements of Logistics Performance Index (LPI), which is a measure applied for strategic planning [25], as transport network increases the security of social and economic life [4].

Road transport is the most frequently uses one. Unfortunately, the transport sector belongs to those sectors that are characterized by the highest growth in the scope of fuels consumption [1], which is reflected in its negative impact on the natural environment. Transport directly affects human health through emitting chemical compounds into the atmosphere [15; 9]. Means of transport are included into the group of factors that cause carbon emission [13]. However, it needs to be remembered that modern transport infrastructure decreases costs in the economy, which is reflected in a territorially sustainable development of the country and reduced negative influence of the economy on the natural environment [5]. Taking initiatives in the scope of development and improvement of transport infrastructure will contribute to reduced air pollution and improved quality of social life.

Methodology

In order to achieve the assumed goal in the scope of determining the dynamic dependence between road transport infrastructure development and emission of air pollutants the Authors applied econometric tools associated with vector autoregression model, namely: Granger causality relationship, impulse response function and variance prediction error decomposition. The tools applied make it possible not only to identify the direction of causality relationship between emission of pollutants into the air and infrastructure and energy consumption in road transport, but also allow to determine the strength of mutual relationships between these variables [24].

The VAR models are the starting point for the further study over the impact of road transport infrastructure development on air pollutant emissions [Osińska, 2006]:

$$\begin{bmatrix} \Delta\ln(\mathrm{P})_t \\ \Delta\ln(E)_t \\ \Delta\ln(I)_t \end{bmatrix} = \begin{bmatrix} \alpha_{10} + \alpha_{11}\mathrm{t} \\ \alpha_{20} + \alpha_{21}\mathrm{t} \\ \alpha_{30} + \alpha_{31}\mathrm{t} \end{bmatrix} + \sum_{k=1}^{p} \begin{bmatrix} \theta_{11,k} & \theta_{12,k} & \theta_{13,k} \\ \theta_{21,k} & \theta_{22,k} & \theta_{23,k} \\ \theta_{31,k} & \theta_{32,k} & \theta_{33,k} \end{bmatrix} \begin{bmatrix} \Delta\ln(\mathrm{P})_{t-k} \\ \Delta\ln(E)_{t-k} \\ \Delta\ln(I)_{t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{bmatrix}, \quad (1)$$

or

$$Y_t = A_0 D_t + \sum_{k=1}^{p} \Theta_k Y_{t-k} + \varepsilon_t, \quad (2)$$

where: $\mathbf{Y_t}$ =[$\Delta\ln(P)_t$, $\Delta\ln(E)_t$, $\Delta\ln(I)_t$]^T – vector of current values observation of endogenous variables: percentage log return of air pollutant emissions by road transport, percentage log return of road transport energy use, percentage log return of road transport infrastructure indicator, p is the optimal log length chosen on the basis of the information criteria set (Akaike criterion-AIC, Schwarz Bayesian criterion - BIC, Hannan-Quinn criterion-HQC), $\mathbf{D_t}$ =[1, t]^T – vector of deterministic variables (constant or linear trend), $\mathbf{A_0}$ =[α_{ij}] (i=1, 2, 3 and j =0,1) – matrix of parameters corresponding to deterministic variables, $\mathbf{\Theta_k}$ =[$\theta_{ij,k}$] (i, j=1, 2, 3 and k =1,2,..,p) – matrices of parameters corresponding to vectors of lagged endogenous variables, $\theta_{ij,k}$ are the short-run adjustment parameters, $\boldsymbol{\varepsilon_t}$ =[$\varepsilon_{1,t}$, $\varepsilon_{2,t}$, $\varepsilon_{3,t}$]^T – vector of error terms presumed to be uncorrelated with mean zero and finite covariance matrix, t = 1,2,…, T.

The traditional Wald tests for the joint significance of all estimates of the short-run adjustment parameters connected with the given variable in each equation are computed in order to identify the direction of any causal relationship between the variables (the short-run Granger causality test) [24].

It is needed to transform the reduced VAR model into the structural VAR in order to be able to evaluate the strength of relationship between the road transport infrastructure development and air pollutant emissions by means of the Impulse Response Function and variance decomposition of prediction errors [16]:

$$BY_t = \Gamma_0 D_t + \sum_{k=1}^{p} \Gamma_k Y_{t-k} + \zeta_t, \quad (3)$$

for

$$A_0 = B^{-1}\Gamma_0, \ \Theta_k = B^{-1}\Gamma_k, \ \varepsilon_t = B^{-1}\zeta_t, \quad (4)$$

if **B** is non-singular matrix.

Impulse Response Function allows to show the strength of the reaction force of the variable that describes emission of pollutants into the air in road transport per unit change of other variables included in the structure of a multidimensional system, that is transport infrastructure development or energy consumption in road transport. Making use of the representation of the moving average for the VAR model in the reduced form, endogenous variables of the analysed system can be described by means of random components of the structural model [16]:[1]

$$Y_t = \mu + \sum_{s=0}^{\infty} \Theta_1^s \varepsilon_{t-s} = \mu + \sum_{s=0}^{\infty} \Theta_1^s B^{-1} \zeta_{t-s} = \mu + \sum_{s=0}^{\infty} \Phi_s \zeta_{t-s}, \quad (5)$$

where the element $\varphi_{ij}(s)$ (i,j = 1, 2, 3 and s= 1,2,…) of matrix Φ_s describes the response of i-th variable in the system at the moment t to a unit disorder of random component j-th variable in the system from the period t-s, at lack of analogous disorders of random components of the remaining variables. This is an interpretation of the impulse response function for the delay s.

The equation (5) makes it possible to forecast future states of the system:

$$Y_{t+h} = \mu + \sum_{s=0}^{\infty} \Phi_s \zeta_{t+h-s}, \quad (6)$$

with the prediction error defined by the following relation:

$$Y_{t+h} - E_t(Y_{t+h}) = \sum_{s=0}^{\infty} \Phi_s \zeta_{t+h-s}. \quad (7)$$

Prediction error variance for i-th system variable for h future periods can be assessed on the basis of the following formula [27]:

$$\sigma_i^2(h) = \sum_{j=1}^{3} \left[\sigma_j^2 \cdot \sum_{s=0}^{n-1} \left(\varphi_{ij}(s)\right)^2\right], \quad (8)$$

while decomposition of the prediction error variance can be conducted (8), so as to determine the shares of disorders attributed to particular equations of the VAR model in this variance:

$$w_j = \frac{\sigma_j^2 \cdot \sum_{s=0}^{n-1} \left(\varphi_{ij}(s)\right)^2}{\sigma_i^2(h)} \cdot 100\%, \quad (9)$$

where w_i – percentage share of ζ_{jt} disorder in the forecast variance for i-th variable.

[1] Dla uproszczenia przyjęto założenie, że wektor zmiennych deterministycznych zawiera tylko stałą μ, a p=1.

Data and Empirical Results

The following variables have been subject to analysis:

- final energy consumption in road transport in kilogram of oil equivalent per capita,
- total length of road (the sum of length of motorways, length of e-roads and length of other roads) in kilometre per capita,
- total number of passenger cars, motor coaches, buses and trolley buses, lorries, road tractors per capita,
- nitrogen oxides emission by road transport in kilograms per capita.

The analysis has been conducted for data observed in the years 1991-2015. The selection of the period to be analysed was the result of the availability and completeness of data in Eurostat database.

The analyses have been conducted for the Visegrad Group due to similar conditionings of economic development and taking joint initiatives. In case of road transport emission of pollutants is mainly connected with the process of fuels combustion, thus energy consumption. The pace of economic growth depends, inter alia, on the length of various types of roads, the network of which allows to distribute properly the intensity of traffic. The variables that determine the air pollution level include nitrogen oxides as it is thought to be the leading pollutant from transport, which contributes to acidification, formation of ground level ozone and particulate formation.

The ADF-GLS test is used to determine the order of integration of time series data, which refers to road transport energy consumption per capita, length of road per capita, number of cars per capita and per capita nitrogen oxides emission by road transport. This test verifies the presence of unit roots in demeaned or detrended time series in accordance with the GLS procedure suggested by Elliott, Rothenberg and Stock [7]. The maximum lag order for the ADF equation is set on the basis of the optimization of the modified Schwarz Bayesian information criterion (MBIC), which is computed according to the revised method recommended by Perron and Qu [17].

Table 1. Results of the ADF-GLS test for the Visegrad Group countries

Country	NO_x emissions	Energy use	Number of cars	Length of roads
Levels				
Czech Republic	-1,8982 (0) c+t	-0,7445 (0) c+t	-2,1703 (0) c+t	-1,0751 (0) c+t
Hungary	-2,3675 (0) c+t	-1,2369 (0) c+t	-1,6594 (0) c+t	-1,9555 (0) c+t
Poland	-1,4741 (0) c+t	-1,5179 (0) c+t	-1,5298 (0) c+t	-2,2552 (0) c+t
Slovakia	2,8369 (0) c+t	-1,5703 (2) c+t	-1,1343 (0) c+t	-2,0474 (0) c+t
First differences				
Czech Republic	$-2{,}3125^{**}$ (0) c	$-1{,}8414^{*}$ (1) c	$-2{,}8082^{***}$ (0) c	$-4{,}6604^{***}$ (0) c+t
Hungary	$-2{,}1404^{**}$ (0) c+t	$-2{,}6643^{***}$ c	$-3{,}3967^{***}$ (0) c+t	$-4{,}9230^{***}$ (0) c
Poland	$-2{,}7939^{***}$ (0) c	$-3{,}3262^{***}$ (0) c	$-2{,}5279^{**}$ (1) c	$-5{,}0801^{***}$ (0) c
Slovakia	$-1{,}6231^{*}$ (2) c	$-7{,}1417^{***}$ (0) c	$-3{,}0092^{***}$ (1) c	$-2{,}0474^{***}$ (0) c
Decision	I(1)	I(1)	I(1)	I(1)

Note: all variables in natural logs, lag length determined via MBIC in parentheses, ADF regression specification in deterministic part: c – constant, c+t – constant and linear trend, *, **, *** denote statistical significance respectively at the 10%, 5%, 1% level.

The results of the ADF-GLS unit root tests presented in Table 1 indicate at the non-stationarity of all variables and stationarity of their first differences, so one may conclude that each variable is integrated of order one (I(1)). Having determined the integration order for all variables (d=1), it is possible to evaluate several lag length criteria to select the optimal lag order *p* in the vector autoregressive model. Hence, VAR(p) models (1)-(2) for first differences of analysed variables are estimated and basic diagnostic tests are carried out. The correlogram of residuals and squared residuals allows to exclude the existence of serial correlation effect, what is also confirmed by the results of Lagrange multiplier tests. Results of the Doornik-Hansen test allow for the rejection of the null hypothesis about the normality of residuals at significance level 0.01 only for the second analysed system in the case of Hungary and Slovakia. The VAR models for both sets of variables are stable with all roots within the unit circle.[2] Therefore, above mentioned results allow to conduct the Wald test for Granger causality for two systems: the first system includes nitrogen oxides indicator, energy consumption indicator and transport infrastructure indicator describing the cars' number per capita, while in the second system per capita length of roads plays the role of the transport infrastructure indicator (see Table 2).

Table 2. The results of the Wald test for the Granger causality – the Visegrad Group countries

Dependent variable	Sources of causation (independent variables)					
	First system: NOx emissions, energy use, number of cars			Second system: NOx emissions, energy use, length of roads		
	Czech Republic					
	$\Delta\ln NO_x$	$\Delta\ln E$	$\Delta\ln I$	$\Delta\ln NO_x$	$\Delta\ln E$	$\Delta\ln I$
$\Delta\ln NO_x$	-	1,4797 [0,261]	5,3706** [0,019]	-	1,2054 [0,286]	10,225*** [0,005]
$\Delta\ln E$	8,9587*** [0,003]	-	6,0196** [0,013]	2,9089 [0,105]	-	0,0610 [0,808]
$\Delta\ln I$	7,9875*** [0,005]	3,7291** [0,049]	-	1,3665 [0,258]	0,8769 [0,361]	-
Hungary						
$\Delta\ln NO_x$	-	3,5623* [0,075]	5,9459** [0,025]	-	2,2166 [0,153]	0,0874 [0,771]
$\Delta\ln E$	3,5658* [0,074]	-	4,9124* [0,039]	1,8272 [0,192]	-	0,7224 [0,406]
$\Delta\ln I$	0,2757 [0,606]	0,0015 [0,962]	-	0,9853 [0,333]	1,2149 [0,284]	-
Poland						
$\Delta\ln NO_x$	-	9,347*** [0,002]	0,9841 [0,397]	-	2,2836 [0,147]	2,1051 [0,163]
$\Delta\ln E$	6,457*** [0,009]	-	0,3435 [0,715]	7,2732** [0,014]	-	1,4949 [0,236]
$\Delta\ln I$	22,124*** [0,000]	27,431*** [0,000]	-	1,7112 [0,206]	2,8868 [0,106]	-
Slovakia						
$\Delta\ln NO_x$	-	4,4477** [0,048]	24,336*** [0,000]	-	5,6738** [0,028]	0,0816 [0,778]
$\Delta\ln E$	5,3415** [0,032]	-	3,3125* [0,085]	5,8291** [0,026]	-	0,0973 [0,759]
$\Delta\ln I$	0,0386 [0,846]	1,9128 [0,183]	-	1,2412 [0,279]	1,0683 [0,314]	-

Note: *, **, *** denote statistical significance respectively at the 10%, 5%, 1% level. Significance implies that independent variable Granger causes the dependent variable. I mean road transport infrastructure indicator: number of cars per capita (first system) or length of roads per capita (second system).

While analysing the results presented in Table 2 one can notice that significant short-term causality relationships have been identified among the variables being elements of the first system, in the second system in turn relationships of this kind between endogenouos variables occurred rarely. In the second system, the results of Wald test provide evidence for existence of unidirectional Granger causality running from the roads' length to nitrogen oxides emissions in the Czech Republic and also

[2] Results of diagnostics tests for VAR models are available from the authors upon request.

unidirectional Granger causality running from the air pollutant emissions to energy consumption in Poland. The bidirectional Granger causality exists between road transport energy consumption and nitrogen oxides emissions in Slovakia, whilst there is no causality (in any direction) between endogenous variables in the second system for Hungary. Therefore, it is difficult to present the common causality pattern between road transport energy use, nitrogen oxides emissions and length of roads in the Visegrad Group countries.

In case of the first system one can indicate the occurrence of bi-directional Granger causality relationship between energy consumption in road transport and nitrogen oxides for Hungary, Poland and Slovakia. Thus, it can be assumed that in these countries the growth of conventional fuels consumption contributes to increased emission of pollutants into the atmosphere, in particular such harmful compounds as nitrogen oxides. On the other hand, the EU transport policy aims at tightening the fuel purity standards, development of bio-fuels market and electrical vehicles may contribute to replacing old car models with new ones, and what follows decreasing the energy consumption while performing transport services. One can interpret in an equivalent way the occurrence of a one-directional causality relationship from nitrogen oxides emission in road transport to energy consumption for the Czech Republic. Occurrences of short-term feedbacks between the number of cars and nitrogen oxides emission and the number of cars and energy consumption for the Czech Republic have also been identified. For Slovakia and Hungary in turn, the number of cars is the Granger cause for energy consumption in road transport as well as for air pollutants emission.

Occurrences of causality relationships of the same direction between the analysed in the system first variables of the Visegrad Group countries may constitute an important piece of information for the decision-makers while formulating goals of transport policy and also while developing the plans of road transport infrastructure development.

In turn, examining the influence of innovations assigned to particular variables in the system on nitrogen oxides emissions may provide useful information about the short-run changes in air pollutant emissions caused by unexpected changes in road transport energy use and development of road transport infrastructure. Impulse responses, which are presented in Figures 1-4 for the Visegrad Group countries, show how nitrogen oxides emission responds to a shock in energy use or transport infrastructure initially and whether the effect of the shock is persistent or temporary.

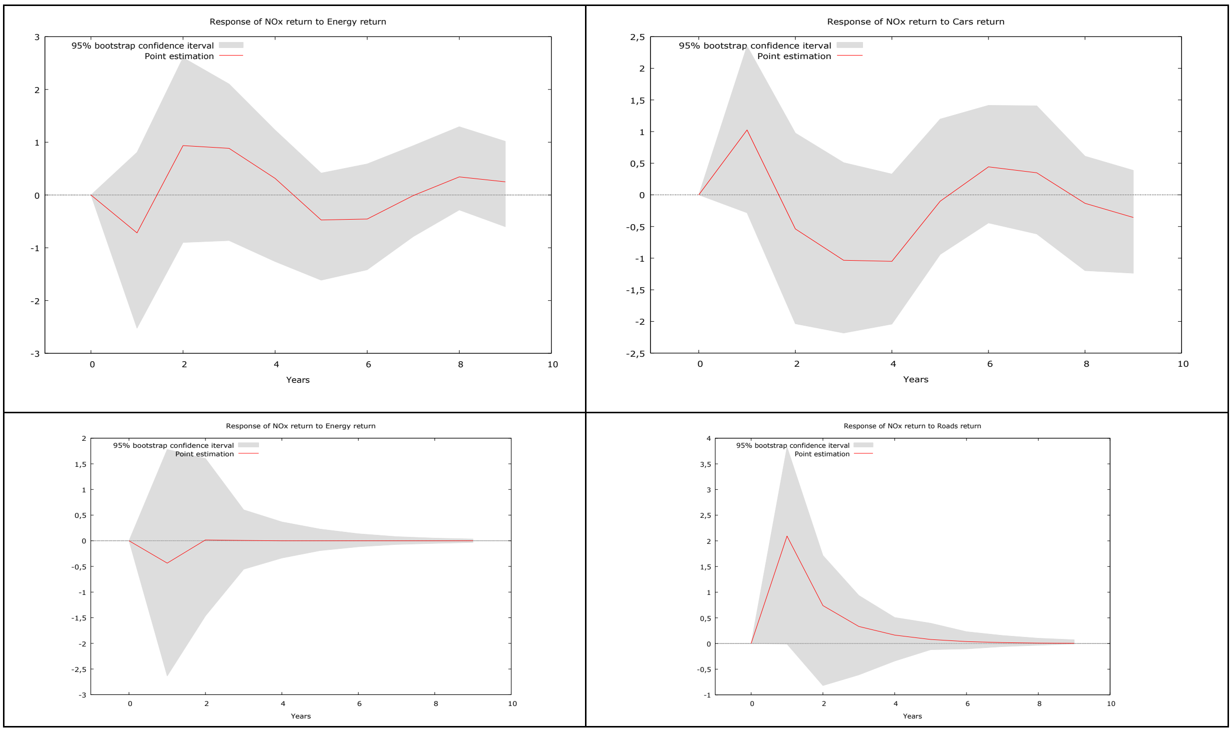

Fig. 1. Impulse responses of ΔNO_x to one standard deviation innovations in ΔE and ΔI for the Czech Republic: first specification – upper panel, second specification – lower panel

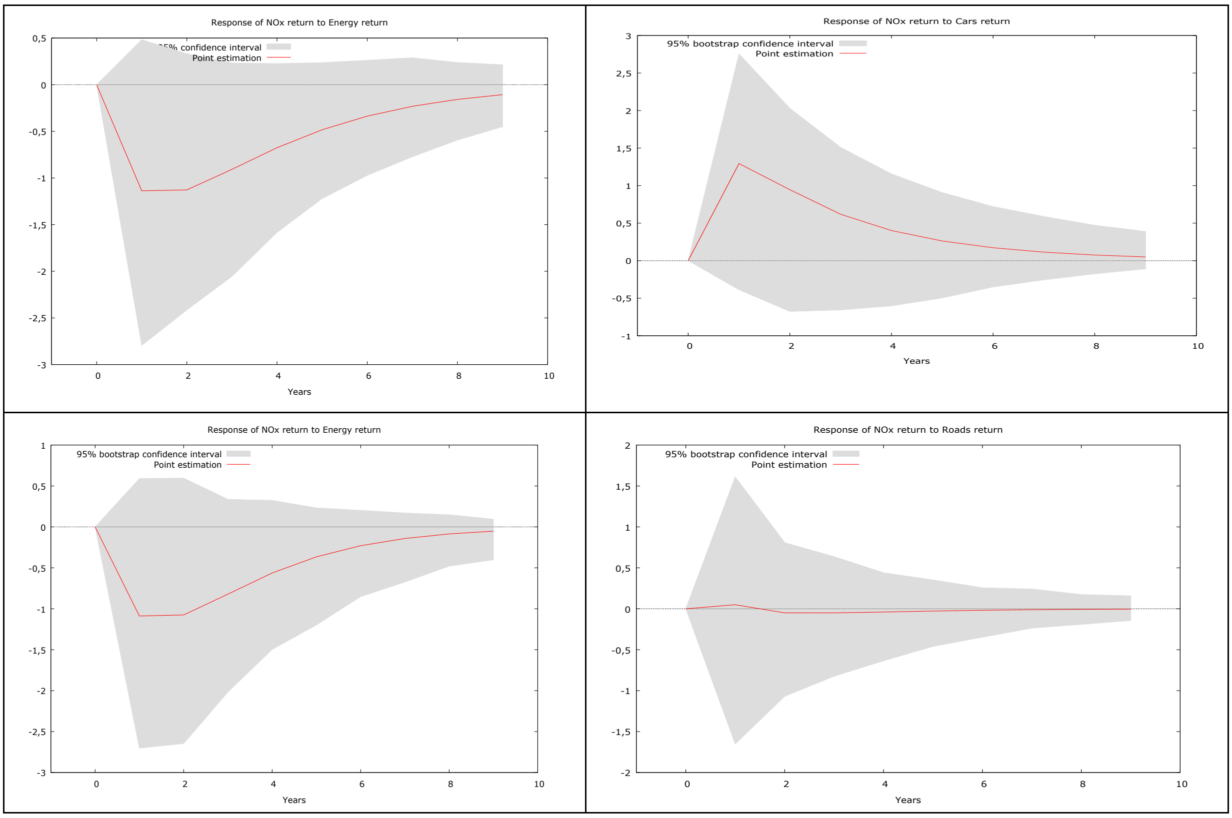

Fig. 2. Impulse responses of ΔNO_x to one standard deviation innovations in ΔE and ΔI for Hungary: first specification – upper panel, second specification – lower panel

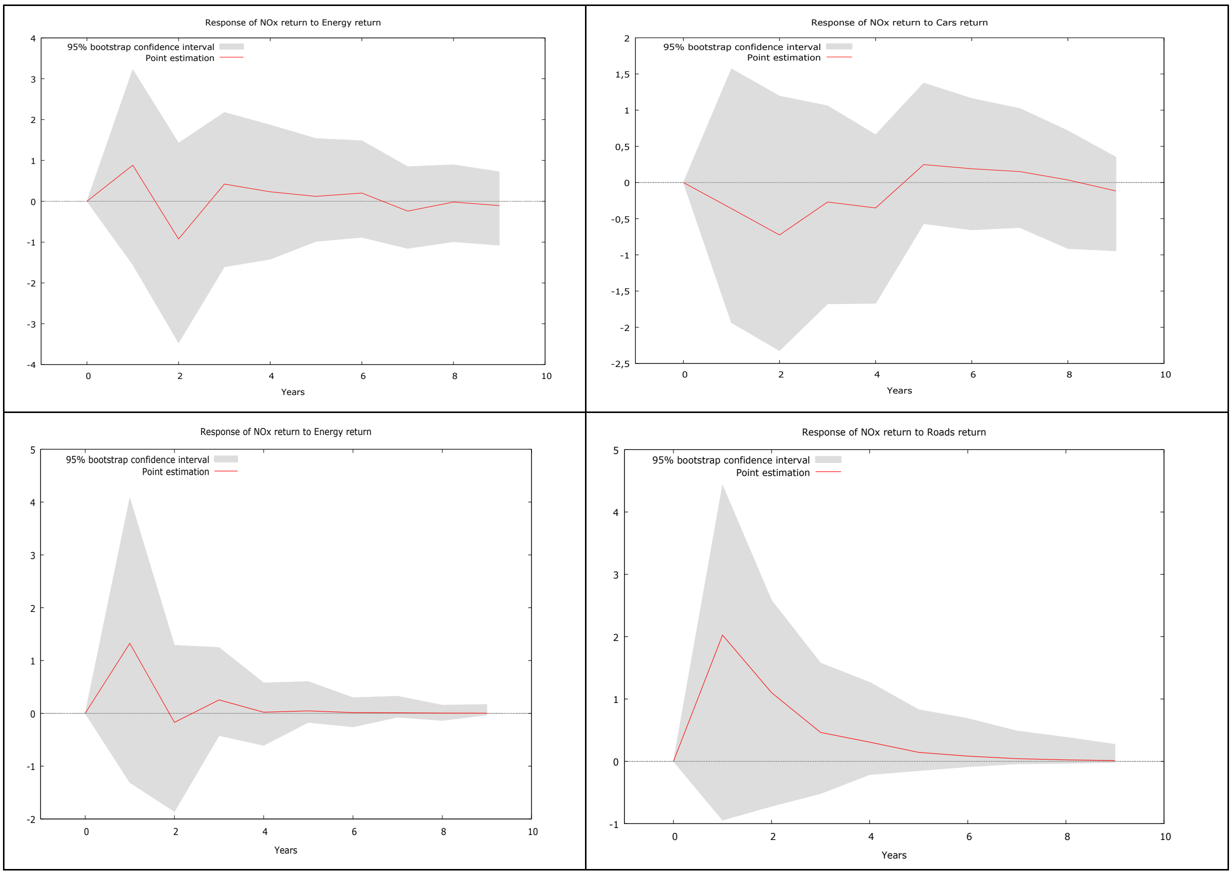

Fig. 3. Impulse responses of ΔNO_x to one standard deviation innovations in ΔE and ΔI for Poland: first specification – upper panel, second specification – lower panel

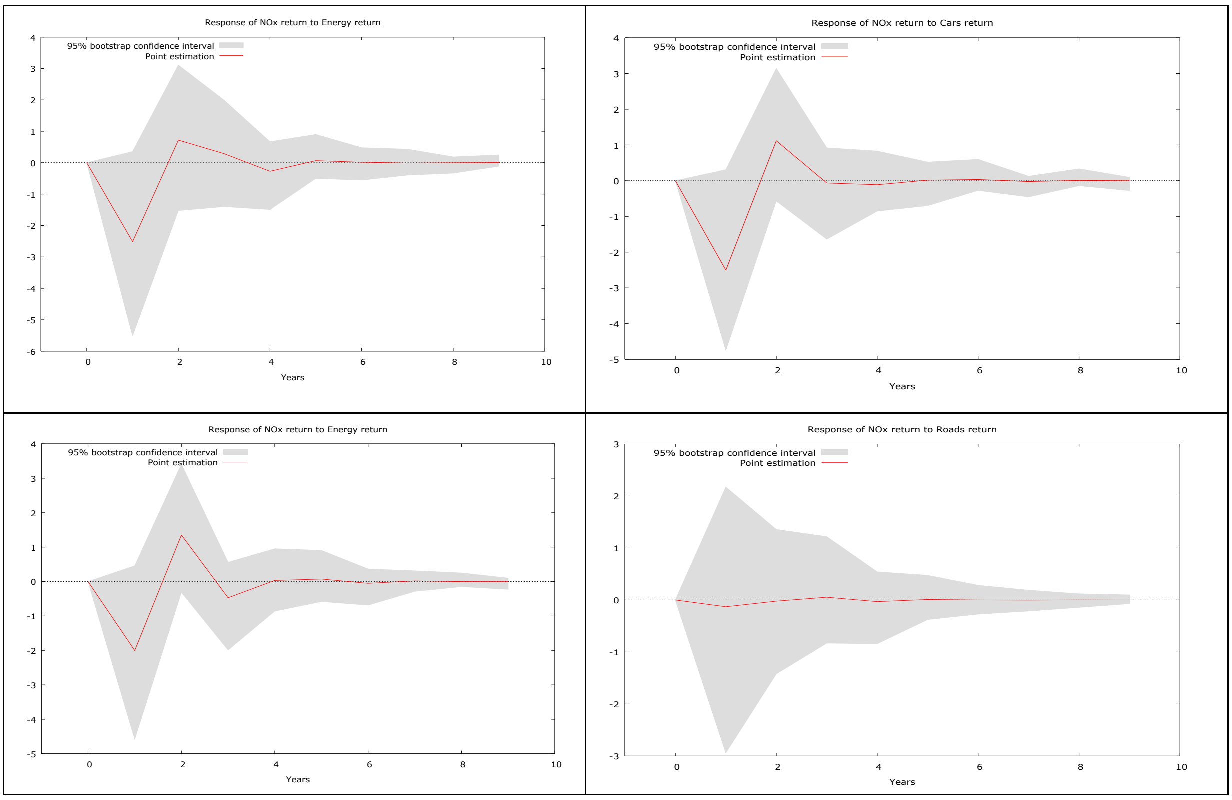

Fig. 4. Impulse responses of ΔNO_x to one standard deviation innovations in ΔE and ΔI for Slovakia: first specification – upper panel, second specification – lower panel

The reaction of NO_x emission growth in road transport to the impulse of the size of one standard deviation from energy consumption growth is strong and lasts for 3-4 further years for all the Visegrad Group countries. However, after that time it is strongly supressed for the Czech Republic and Slovakia. In case of Poland and Hungary the reaction of nitrogen oxides emission growth to the same impulse lasts longer and is suppressed more slowly. This constitutes a confirmation for the identified Granger causality relationship between energy consumption and NO_x emission for the Czech Republic, Hungary and Slovakia. The reaction of nitrogen oxides emission growth to the impulse from the car number growth side is definitely weaker and supressed quickly for the Czech Republic, Hungary and Slovakia. The reaction of nitrogen oxides emission growth to the impulse from the road length growth side is the strongest for Hungary and Slovakia, but after 3 years this impulse is already much supressed, and after 10 years it is practically invisible. For the Czech Republic and Poland, the reaction of NO_x emission growth to the impulse triggered by the road length growth is weaker. It is worth stressing here that a quick reaction to the impulses occurring in the system and their quick suppression confirm the stability of the system. Thus, the reaction of NO_x emission growth to the impulse from the energy consumption growth side in the first system indicates rather its instability in case of Poland and Hungary. Strong responses of nitrogen oxides emission to the impulse from the side of energy consumption and number of cars may indicate a high level of dependence between these variables in the Visegrad Group countries.

In turn, the variance decomposition of prediction error indicates which part of nitrogen oxides emission volatility may be explained by the variability of road transport energy consumption or changes in road transport infrastructure. The variance decomposition of prediction error for air pollutant emission indicator has been summarized in table 3.

Table 3. The results of the variance decomposition of prediction error for ΔNOx

Horizon	First specification			Second specification		
Impulse from	ΔNOx	ΔE	ΔI	ΔNOx	ΔE	ΔI
Czech Republic						
0	100	0	0	100	0	0
1	93,7212	2,0638	4,2150	84,7890	0,6317	14,5793
5	83,2914	6,5633	10,1452	83,7093	0,5896	15,7011
	80,9948	7,9791	11,0261	83,6979	0,5891	15,7130
Hungary						
0	100	0	0	100	0	0
1	84,4288	6,7875	8,7838	94,4397	5,5489	0,0114
5	73,1162	14,8574	12,0265	87,3882	12,5779	0,0339
10	71,9313	15,9956	12,0731	86,7465	13,2152	0,0383
Poland						
0	100	0	0	100	0	0
1	98,1453	1,5900	0,2647	87,8918	3,6297	8,4785
5	94,8026	3,5682	1,6292	85,8872	3,4943	10,6185
10	94,4081	3,7383	1,8536	85,8539	3,4921	10,6541
Slovakia						
0	100	0	0	100	0	0
1	75,4406	12,3225	12,2369	92,0406	7,9261	0,0333
5	72,7910	13,0898	14,1192	88,5814	11,3790	0,0396
10	72,7872	13,0943	14,1184	88,5684	11,3918	0,0398

Note: variables order in the Cholesky decomposition: ΔE, ΔI, $\Delta NO_{x.}$

The results of prediction error variance decomposition for nitrogen oxides emission growths confirm the results of Granger causality relationship and impulse response function. The prediction error of NO_x emission growths to the largest extent depends on their delayed values for all the countries of the Visegrad Group. The share of energy consumption growths in the prediction error of nitrogen oxides emission growths varies from 1,59% in case of Poland to 12,32% in case of Slovakia in a one-year forecast horizon. The share of the car number growths in the prediction error of nitrogen oxides emission growths varies from 0,26% in case of Poland and to 12,24% in case of Slovakia in a one-year forecast horizon. As the forecast horizon lengthens the share of car number growth significantly increases in the prediction error of nitrogen oxides emission growth for the Czech Republic, Hungary and Slovakia. In turn, the share of length of roads growth in the prediction error of nitrogen oxides emission growths is the largest for the Czech Republic and Poland, as in a one-year horizon it amounts respectively 14,58% and 8,48%. The values of prognosis error decomposition of nitrogen oxides emission growths confirm the earlier observations with regard to occurrence of significant relationships among the analysed variables in the first system.

It would be worth to deepen the conducted analysis through considering additional control variables in the analysis, for example the age of cars or engine type, and also the share of bio-fuels in energy consumption. Moreover, it would be useful to make use econometric tools that enable to identify non-linear relationships between the analyses endogenous variables. Unfortunately, the length of time series available for the Visegrad Group made it impossible to conduct analyses of this kind at this stage.

Conclusions

Due to the negative impact of transport processes on the natural environment, in the first place those means of transport should be promoted that are environmentally-friendly. The dominant road transport should be then replaced by rail and water transport. Unfortunately, in the majority of European countries, including the Visegrad Group ones, the share of road transport is growing or remains at the same level in the years to come in case of freight, which has a particularly negative influence on the environment and road safety. Thus, the priority of sustainable transport strategy should be bridging the demand asymmetry directed at road transport. However, another solution may be making investments in modern logistic transport infrastructure, which thanks to optimum management of traffic intensity reduces the negative influence on the natural environment, mainly through air pollution reduction. Air pollution constitutes the most important problem of road transport functioning.

The research conducted has demonstrated that the emission of nitrogen oxides is to the largest extent affected by the amount of consumed energy and number of cars. However, this impact may be treated as a derivative of transport infrastructure development measured with the length of roads.

While analysing the dynamics of changes in the scope of the length of motorways in the Visegrad Group countries one can observe a slight average annual growth in this respect in the years 1991-2015, the largest in Hungary and Poland (respectively by 8,13% and 8,45%), while it was mainly caused by the growth in the motorways length after these countries accessed the European Union in 2004. Lack of modern infrastructure is reflected in an uneven distribution of traffic intensity, traffic jams, which cause air pollutants emission growth, in this nitrogen oxides. Investments into the road infrastructure, its modernisation, and first of all an increase in the motorway's length are some of the ways to limit the negative impact of road transport on the natural environment.

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