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Summary: Air pollutant emission generated by road transport is often the side-product of exhaust emission, which is derived from fuels combustion process. The increase of road traffic, caused inter alia by such factors as the economic growth, rapid urbanization, change in the life standards, improve of road infrastructure, leads to the increase of road-transport related energy consumption and air quality deterioration. In order to improve air quality, especially in urban area, environmental management instruments ought to be used by policy makers who are responsible for transport development. Their effectiveness may be strengthened through the use of econometric tools by means of which it is possible to identify the drivers of air pollutant emissions in transport sector. Hence, in this paper the existence of the long-run equilibrium relationship between carbon dioxide emissions and GDP, energy consumption, fuels prices, urbanization ratio is checked in transport sector of chosen European countries. The background of empirical research constitutes the environmental Kuznets curve (EKC) hypothesis. This hypothesis is verified using different cointegration tests: Hansen parameter instability test, Park added variables test, Engle-Granger and Phillips-Ouliaris residual-based tests.
Keywords: transport sector, carbon dioxide emission, environmental management, econometric tools.

1. Introduction

Recently the quality of natural environment has been considered in terms of public good, the value of which is decrease, among others, through emission of pollutions connected with growing energy demand on the side of various groups of stakeholders in the society. More and more often the relationship between the quality of the natural environment and the quality of human life and the health of whole societies is emphasized. Guarito and Volta (2017) stress the existence of links between air pollutant concentrations and health impacts, which may be shown by means of the "years of life lost” indicator. Its value informs that almost 507.4 million inhabitants of the EU may lose on average more than three days of life each year due to the high concentration of PM2.5. This indicator takes the worse value in highly populated areas, such as urban areas [5]. Petrescu et. all (2015) underline the negative impact of traffic–related air pollution, especially PM10 fraction, on human health. According to them, it is an urgent need for an adequate and continuous monitoring of air pollutant emissions generated by road transport due to the increasing number of vehicles as well as the growing population of urban regions that are exposed to consequences of air pollution [15]. Therefore, more and more attention is devoted to the transport impact on the environmental degradation, because both exhaust emissions and non-exhaust road dust emissions are important factors of air quality. It is worth stressing that non-exhaust emissions level is dependent on the vehicle types, but also on tire types, road surface types and climate conditions. Moreover, transport is characterized by the significant increase in both energy consumption level and greenhouse gas emissions in the EU, despite advances in transport technology and the economy activity slowdown after the subprime crisis [12]. In order to improve energy efficiency in transport sector and decouple air pollutant emissions from economic growth, it is needed to introduce the set of environmental management instruments in this sector. Additionally, the use of econometric tools may help policy makers to get to know the drivers of air pollutant emissions in transport sector and evaluate the effectiveness of implemented instruments. The importance of econometric analysis of air pollution level in the development of pro-ecological strategy in the city is stressed by Zawada and Szajt (2016). While implementation of the environmental management instruments has contributed to the control and limiting CO_2 emission in the energy sector, constantly growing CO_2 emission in the transport sector has remained a global problem. A growing demand for transport services (connected with the growing economic activeness or the change of people's standard of life), division of the transportation assignments among individual branches of transport partially neutralize results of the research concerning improved efficiency of fuel consumption, which concern inter alia modifying engine operation, construction of vehicles or an increased share of bio-fuels as compared to conventional fuels.

The aim of this paper is to show the possibility of the use of econometric tools in environmental management process, that is directed at the significance reduction of carbon dioxide emissions in transport sector. These econometric tools are implemented to the verification of the Environmental Kuznets Curve (EKC) hypothesis in transport sector of chosen EU countries. The inclusion of the additional determinants such as energy consumption by the transport sector, fuel prices or urbanization indicator into the EKC model may allow for better explanation the nature of the pollution-income relationship for the transport sector of each analyzed country. These hypothesis are tested using different cointegration techniques proposed by Engle and Granger (1987), Phillips and Ouliaris (1990), Hansen (1992) and Park (1992). The empirical studies are conducted on the basis of the following variables: road transport-related CO_2 emissions, gross domestic product (GDP), road transport-related energy consumption, fuel prices, urbanization ratio for chosen European countries. The rest of the paper is organized as follows. Section 2 briefly presents the negative impact of the transport sector on the environment and human health. In Section 3 both the EKC hypothesis and the econometric tools used for its verification are described. Section 4 describes the data and presents empirical results. And finally, Section 5 concludes the paper.

2. Transport influence on economy and environment

Transport is one of the most vital factors determining economic development of the country, and modern transport infrastructure contributes to the increase of social, economic and spatial integrity of the country and strengthening given country's competitiveness on the international scene. Direct and indirect effects of transport's influence on economy include inter alia [11]:

— increased efficiency of logistics processes in enterprises,
— increase in logistics service efficiency,
— creating favorable conditions for development of logistics centers,
— increased spatial range of markets for the goods,
— creating conditions aiming at decreasing prices, through inter alia mitigating negative impact of space on the cost level of goods manufacturing and services,
— integration of central and peripheral areas, and thus, limiting the phenomenon of social exclusion,
— creating new workplaces in the transport, shipping and logistics sector,
— mobilizing innovative activities in the scope of renewable energy sources use and an increase of fuel efficiency in the transport sector,
— satisfying communication needs of people, as illustrated also by development of tourism.

It is worth stressing the complementarity of transport for other branches of national economy, due to the lack of a substitute for transport activity, as well as occurrence of a feedback loop between transport development and economic conjuncture. The place and role of transport in the management process are determined by factors shaping the size and rate of changes of demand for transport services, that is: size of production potential, production structure, activeness level of social life, level of specialization and cooperation of work sharing, preferences of individual sectors of the economy, economic cycle phase [18]. Transport system may contribute to the growth of competitiveness of a given economy, if it is able to guarantee inter alia: an increased access in time and space to transport services for various profiles of users, limiting the cost and time of performing transport services, energy efficiency improvement and decreasing unit emission benchmarks, eliminating congestion and multimodality [23].

An undeniable problem and at the same time a barrier for transport development in the light of The United Nations Framework Convention on Climate Changes is its dependence on fossil fuels and therefore high benchmarks of greenhouse gases emission into the atmosphere. The adopted during the summit of the European Union in 2008 energy and climate package assumes with regard to transport (included into the economy sectors not covered by the European Emission Trading System, EU-ETS) performing the following goals: reducing greenhouse gasses emission by 10% by 2020 at a simultaneous decrease of CO_2 emission limits by new vehicles to the level of 95g/km, achieving at least a 10% share of renewable fuels in transport fuels use [20]. In order to limit a negative impact of the transport sector on environment the following solutions are recommended [24], [21]:

— increase of energy efficiency in the transport sector through development of intermodal transport in cargo transport, increase of the share of environmentally-friendly means of transport (vehicles and buses using fuel cells and hydrogen and the ones propelled by electricity, gas, hybrid, compressed air), implementing innovative systems of traffic and transport management in particular branches of transport (ITS – road transport, ERTMS – rail transport, SESAR – air transport, VTMS – sea transport, RIS – inland waterway transport);
— investments in low-emission solutions through inter alia decarbonisation of fuels and supporting development of alternative fuels infrastructure, stimulating works on constructing vehicles of lower CO_2 emission, supporting purchases of more environmentally-friendly vehicles by public subjects;
— organizational and system solutions which aim at decrease of transport congestion, particularly in urban areas (inter alia through development of municipal collective transport, promoting pedestrian and bicycle traffic, optimizing municipal and regional systems of passenger transport).

Klooster and Kampman (2006) in turn suggest implementing market mechanisms in order to limit CO_2 emission in the transport sector, similar to the ones functioning in the energy sector. The authors evaluate in their paper the possibility of introducing two types of CO_2 emission allowances trading: Cap & Trade or Baseline & Credit in the whole transport sector or in its particular branches (road, railways, maritime shipping or aviation). Briefly describing, the essence of the Cap and Trade scheme is setting of a fixed ceiling for CO_2 emissions level in combination with tradable emission rights. Each source must hold emissions allowances in order to cover its emissions level, and the saved rights may be sold to the another source. The main feature of Baseline & Credit scheme is that the baseline emission standard in combination with bankable/tradable emission credits is set. The difference between these two type of schemes is that in the B&C scheme the absolute level of CO_2 emissions are not regulated directly, only the relative emissions (the CO_2 emissions per vehicle kilometer) are respected. [8]. Mraihi (2012) indicated for some policy options which may reduce energy intensity from transport sector and in consequences may lead to increase energy efficiency of transport activity. The following policy options are described: logistics solutions, modal shifting, economic structure change, transport planning, fiscal and economic instruments, technological instruments, in order to underline the meaning of decoupling the transport energy consumption from economic growth [8]. The problem of negative impact of the reduction of transport-related energy consumption on economic growth is also underlined by Abdallah et al. (2013). The subject literature also stresses the fact that transport processes generate highest costs within reverse logistics [9].

The above presented issues of transport impact on environment degradation and human health, together with the explanation of the mutual dependencies among energy consumption, economic growth and transport development indicate the relevance of the research problems and importance of econometric analyses conducted in this scope.

3. Cointegration methodology in the identification of the environmental degradation - income relationship for transport sector

In classical approach to modelling the relationship between environmental degradation and economic growth the following quadratic function with the turning point occurring at a maximum pollutant level is used [21]:

$$lnP_t = \alpha_0 + \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + e_t \quad (1)$$

where: P – pollutant emissions level (carbon dioxide emissions in transport sector per capita), Y – income level (real gross domestic product per capita), α_0, α_1, α_2 – estimated parameters, e_t – error term that may be serially correlated.

It is expected that above presented relationship between air pollutant emissions level and income level may be described by bell-shaped curve, if only the sign of α_1 parameter is positive and the sign of α_2 parameter is negative (α_1 > 0 and α_2 < 0). When one plots a graph of the quadratic function (1) and it resembles an inverted U-shaped curve for a chosen country, then one may observe a decoupling of air pollutant emissions from economic growth. It means that air pollutant emission increases in the early stage of economic development until this development reaches a turning point ($Y_{TP} = \exp\left(-\frac{\alpha_1}{2\alpha_2}\right)$) and after that air pollutant emission turns to decrease as income increases. Panayotou (1993) explained this phenomena through the increase in the scale of economy due to the industrial revolution effect and the insufficient technological progress in the area of environmentally friendly solutions in the early stage of economic development. In turn, the structural shift from industrial to the knowledge-based economy, coupled with the more mature attitude of the public to the environmental issues and the popularization of knowledge about environmental management process, caused the reduction of environmental degradation at the higher level of economic development. As Stern (2004) stressed, this hypothesized relationship between indicator of air pollutant emissions and income was named for Kuznets (1955). Therefore, according to the environmental Kuznets curve (EKC) hypothesis, the logarithm of pollutant emissions indicator is mostly modelled as a quadratic function of logarithm of income [17].

In the EKC literature the more sophisticated functional forms, which enable for the impact of other explanatory variables on air pollutant emissions level are considered too. In this study three additional factors are included into the EKC model [3] [4]:

$$lnP_t = \alpha_0 + \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + \alpha_3 lnE_t + \alpha_4 lnFP_t + \alpha_5 lnU_t + e_t \quad (2)$$

where: E –transport energy consumption per capita, FP – fuel prices, U – urbanization ratio, α_3, α_4, α_5 – – estimated parameters.

According to literature studies, the increase of economic activity is accompanied by the increase in transportation demand. In turn, the increase of transportation activities and the rapid growth in the number of private vehicles lead to the fuels consumption rising and air pollutant emissions growth by road transport sector. Therefore, the expected sign of α_3 parameter is positive [3] [19]. The higher fuel prices may cause the limitation of the transportation activity, notably the reduction of transportation needs of households and small private enterprises, and in the same way the reduction of the carbon dioxide emissions by road transport. According to above explanation the expected sign of α_4 parameter is negative [1]. The expected sign of α_5 is mixed depending on the country's attitude to the environmental protection issues and the level of income. According to Hossain (2011), relatively high income countries are more urbanized than low and middle income countries. So, the rapid urbanization process together with weak environmental protection laws may lead to the increase in transportation activity. This phenomena coupled with aging means of transport, unresolved "empty runs" issues, congestion problem may cause the increase of air pollutant emissions by road transport sector in the case of lower income countries (positive sign of α_5 parameter) [25].

The estimates for the relationship (1) or (2) are obtained by means of the Fully Modified Ordinary Least Squares (FMOLS) method. If the existence of the cointegrating relationship between air pollutant emissions indicator and the set of exogenous variables included in the (1) or (2) equation is confirmed, then the α_1, α_2, α_3, α_4, α_5 parameters may be interpreted as the long-run elasticities of air pollutant emissions relative to income, energy consumption, fuel prices level and urbanization level respectively. In order to investigate the cointegrating behaviour of analysed variables the following set of cointegration tests is applied: Hansen parameter instability test, Park added variables test, Engle-Granger and Phillips-Ouliaris residual-based tests. Both Engle-Granger and Phillips-Ouliaris cointegration tests are designed to detect the presence of a unit root in the residuals series derived from the regression that may describe the long-run equilibrium relationship among the air pollutant emissions level, input level, energy consumption level, fuel prices level and urbanization level. Therefore, these procedures, that are directed at the verification of the null hypothesis of the lack of cointegration against the alternative hypothesis of the existence of cointegrating relationship among variables, are compatible with the well-known unit root tests, which verified the null hypothesis of nonstationarity of residuals series against the alternative hypothesis of stationarity. The main difference between these two tests is that the Engle-Granger test is based on a parametric augmented Dickey-Fuller (ADF) methodology, whilst the nonparametric Phillips-Perron (PP) method of accounting for serial correlation in the residuals series is applied in the Phillips-Ouliaris test. Summing up, the following k-order lagged residual regression is estimated in the Engle-Granger test [2]:

$$\Delta e_t = (1 - \rho)e_{t-1} + \sum_{j=1}^{k} \delta_j \Delta e_{t-j} + \mathrm{u}_t \qquad (3)$$

where: k – maximum number of lags is determined using the Schwartz information criterion (SIC), Δe_t – first differences of residuals series, ρ and δ_j (j = 1, ..., k) – estimated parameters. Test statistics used for verification of null hypothesis of the existence a unit root in residuals series (ρ = 1) is given by formula [2]:

$$t(\hat{\rho}) = \frac{\hat{\rho} - 1}{S(\hat{\rho})} = \frac{\hat{\rho} - 1}{s_u \cdot \left(\sum_{t=2}^{T} e_{t-1}^2\right)^{-1/2}} \tag{4}$$

where: $S(\hat{\rho})$ is the OLS estimator of the standard error of the estimated ρ parameter, s_u – degree-of-freedom corrected estimated standard error, T – sample size.

In the first step of the Phillips-Ouliaris test one has to estimate the following [16]:

$$\Delta e_t = (1 - \rho)e_{t-1} + \nu_t \tag{5}$$

where the long-run variances for residuals series are estimated using the Bartlett kernel estimator with a fixed Newey-West bandwidth.

In the second step, test statistics used for verification of null hypothesis of the existence a unit root in residuals series (ρ = 1) is computed in accordance to the following formula [15]:

$$t(\hat{\rho}^*) = \frac{\hat{\rho}^* - 1}{S(\hat{\rho}^*)} = \frac{(\hat{\rho} - 1) - T \cdot \varpi_\nu \cdot \left(\sum_{t=2}^{T} e_{t-1}^2\right)^{-1}}{\omega_\nu^{1/2} \cdot \left(\sum_{t=2}^{T} e_{t-1}^2\right)^{-1/2}} \tag{6}$$

where: ϖ_ν – the estimation of the strict one-sided long-run variance of residuals, ω_ν - the estimation of the long-run variance of residuals.

The Engle-Granger and Phillips-Ouliaris statistics have non-standard asymptotic distributions for which critical values are calculated by means of simulation methods [16].

In parameter instability test proposed by Hansen (1992), the null hypothesis about the existence of cointegrating relationship among air pollutant emissions, input, fuel consumption, fuel prices and urbanization is tested against the alternative hypothesis of no cointegration. According to Hansen, the evidence for the lack of cointegration among analyzed variables is the instability of parameters in the EKC model (1) or (2). Test statistics is derived from the Lagrange Multiplier methodology and a priori knowledge about breakpoint is not required in this test. Asymptotic critical values for this cointegration test were computed by Hansen (1992).

In added variables test proposed by Park (1992), the cointegration among air pollutant emissions, income, road transport energy consumption, fuel prices, urbanization level is assumed in the null hypothesis. Test statistic is computed in order to verify for the significance of spurious time trends in the EKC model (1) or (2). The higher trend terms are added into the test equation, compared to the original equation (1) or (2), and then the Wald test of jointly significance of additional trend coefficients is calculated. This test statistic has asymptotically chi-squared distribution. Under the null hypothesis of cointegration, the residuals series from the EKC model ought to be stationary, so the insignificance of the set of spurious trend coefficients is expected. In turn, the significance of spurious trend terms in the EKC equations may indicate at the remaining stochastic trend in the residuals derived from model (1) or (2). This conforms the lack of cointegration among variables assumed in the alternative hypothesis [14].

4. Verifying the EKC hypothesis for the selected EU countries

Empirical research presented in the paper have been conducted for four selected countries of the European Union: France, the United Kingdom, Finland and Spain. Two first countries are characterized by the greatest share of transport value added created jointly by 27 countries of the European Union (EU-27 value added) (France – 18.1% in the land and pipeline transport sector, the United Kingdom – 21% in the air transport sector)[1]. Spain and Finland in turn belong to the group of EU countries working intensively on establishing an efficient certifying system of bio-fuels use (the level of bio-fuels consumption in the EU increased from 1.1mln Toe in 2002 to 13.6 mln Toe in 2011)[2].

Annual data for this analysis was mainly collected from World Development Indicators (WDI)[3] and for the reason of the time series availability, the sample period ranges from 1961 to 2011. Data used in this study consist of carbon dioxide emissions from transport (P_t; in metric tons per capita), real gross domestic product (Y_t; constant 2005 US dollars per capita), energy consumption from road sector (E_t; in kg of oil equivalent per capita), urbanization ratio (U_t; in percentage). Additionally, fuel prices are represented by retail gasoline prices, that were converted into constant 2005 dollars by means of GDP deflator (FP_t; constant 2005 US dollars per gallon).[4] As it is described in WDI database, CO_2 emissions from transport contain emissions from combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation. In turn, road sector energy consumption is the total energy used in the road sector including petroleum products, natural gas, electricity, combustible renewable and waste. Urbanization ratio shows what is the share of people living in urban areas to the entire population. Analyzed time series are shown in Figures 1–2.

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[1] http://ec.europa.eu/eurostat/statistics-explained/index.php/Land_transport_and_transport_via_pipelines_services_statistics_-_NACE_Rev._2 [accessed 21.03.2016].

[2] http://www.globenergia.pl/aktualnosci/podsumowanie-rynku-biopaliw-w-unii-europejskiej-raport [accessed 21.03.2016].

[3] http://data.worldbank.org/indicator [accessed 03.02.2016].

[4] https://energy.gov/eere/vehicles/fact-915-march-7-2016-average-historical-annual-gasoline-pump-price-1929-2015 [accessed 03.11.2016].

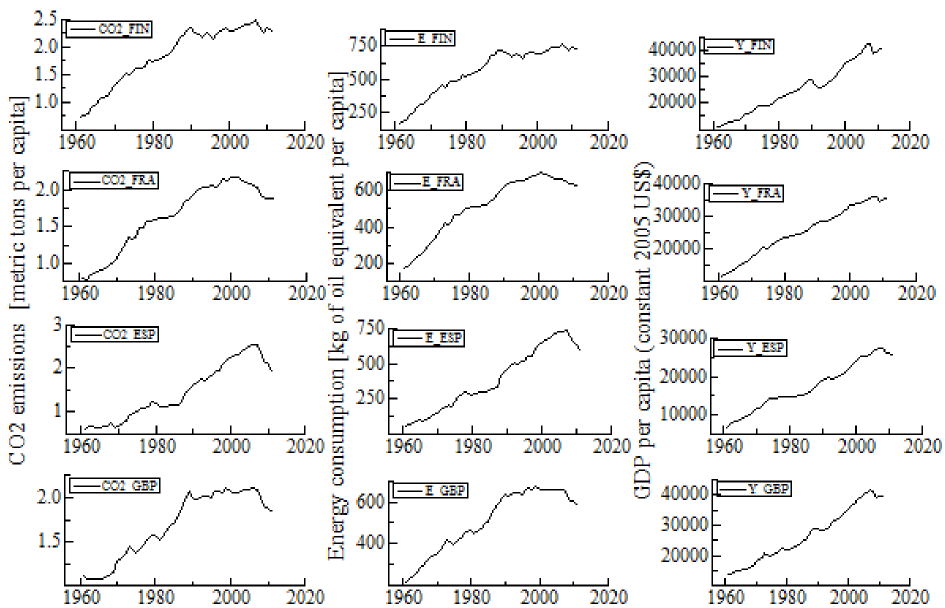

Fig. 1. Shaping of CO_2 emissions, energy consumption in transport sector and real GDP per capita in Finland (first panel), France (second panel), Spain (third panel) and the United Kingdom (fourth panel) from 1961 to 2011

Source: own elaboration.

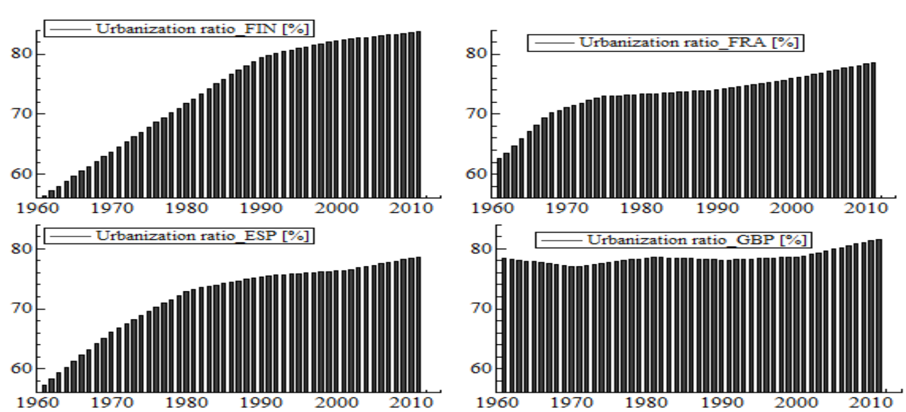

Fig. 2. Shaping of urbanization ratio in Finland, France, Spain and the United Kingdom from 1961 to 2011

Source: own elaboration.

All variables are expressed in natural logarithms, because this transformation of data helps to induce stationarity in the variance-covariance matrix. In order to establish the order of integration of the analyzed time series the author used unit roots tests (Augmented Dickey-Fuller Generalized Least Squares (ADF-GLS) and Schmidt-Phillips) for logarithms of the variables and their first differences (comp. Tables 1–4). Moreover, a very important issue while evaluating time series stationarity is identifying occurrences of potential structural breaks. For this reason the author also conducted the structural break unit roots test of Zivot and Andrews (1992), in which the null hypothesis on unit roots occurrence was verified against an alternative one on the stationarity with a structural break in the intercept and trend coefficient (comp. Tables 1–4).

Table 1. The results of unit root tests for Finland

Variables	Levels				Differences	
	ADF-GLS (c+t)	Zivot-Andrews (c+t) break	Break date	Schmidt-Phillips (rho)	ADF-GLS (c)	Schmidt-Phillips (rho)
P_t	−0.778 [3]	−2.700 [0]	1990	−2.988 [3]	-2.192 [2]**	−58.345 [2]***
Y_t	−2.316 [1]	−4.358 [1]	1990	−8.797 [1]	−4.378 [0]***	−26.745 [0]***
Y_t^2	−2.536 [1]	−4.504 [1]	1990	−9.821 [1]	−4.441 [0]***	−26.999 [0]***
E_t	−0.887 [3]	−3.173 [0]	2008	−2.273 [2]	−2.373 [1]**	−57.119 [1]***
U_t	−2.546 [3]	−5.090 [2]*	1986	−0.396 [3]	−2.506 [2]*	−4.818 [2]
FP_t	−0.980 [0]	−3.748 [1]	1997	−5.362 [3]	−5.667 [0]***	−36.211 [1]***

Note: (***), (**), (*) in ADF-GLS , Schmidt-Phillips and Zivot-Andrew tests respectively indicate the rejection of the null hypothesis that series has a unit root at 1%, 5% and 10% levels of significance. The numbers inside the brackets are the optimum lag lengths determined using Akaike information criterion. Intercept and trend specification in the regression models were chosen for variables levels and only intercept for variables differences.

Source: own calculation.

Table 2. The results of unit root tests for France

Variables	Levels				Differences	
	ADF-GLS (c+t)	Zivot-Andrews (c+t) break	Break date	Schmidt-Phillips (rho)	ADF-GLS (c)	Schmidt-Phillips (rho)
P_t	−1.166 [3]	−1.263 [0]	1989	−3.881 [3]	−2.484 [2]**	−24.259 [1]**
Y_t	−0.807 [1]	−2.655 [1]	1975	−1.783 [1]	−3.053 [0]***	−37.678 [1]***
Y_t^2	−0.841 [1]	−2.754 [2]	1973	−2.165 [1]	−3.265 [0]***	−37.813 [1]***
E_t	−1.255 [3]	−3.137 [2]	2001	−2.676 [3]	−2.110 [1]**	−24.683 [1]**
U_t	0.320 [10]	−8.871 [1]***	1975	−0.878 [3]	−1.621 [9]*	−6.965 [2]

Source: own calculation.

Table 3. The results of unit root tests for Spain

Variables	Levels				Differences	
	ADF-GLS (c+t)	Zivot-Andrews (c+t) break	Break date	Schmidt-Phillips (rho)	ADF-GLS (c)	Schmidt-Phillips (rho)
P_t	−0.954 [1]	−2.784 [0]	2005	−4.022 [1]	−4.617 [0]***	−28.927 [0]***
Y_t	−1.133 [1]	−3.329 [4]	2008	−1.233 [1]	−1.766 [0]*	−15.646 [0]*
Y_t^2	−1.259 [1]	−3.352 [4]	2008	−1.949 [1]	−1.916 [0]*	−15.126 [0]*
E_t	−0.681 [1]	−2.186 [0]	2002	−3.593 [1]	−4.357 [0]***	−41.911 [0]***
U_t	−2.626 [3]	−3.815 [1]	1975	0.062 [1]	−1.238 [10]	−3.249 [3]

Source: own calculation.

Table 4. The results of unit root tests for the United Kingdom

Variables	Levels				Differences	
	ADF-GLS (c+t)	Zivot-Andrews (c+t) break	Break date	Schmidt-Phillips (rho)	ADF-GLS (c)	Schmidt-Phillips (rho)
P_t	−0.873 [1]	−3.250 [1]	1995	−2.924 [1]	−3.679 [0]***	−31.343 [1]***
Y_t	−2.588 [1]	−4.031 [6]	2009	−10.813 [1]	−4.730 [0]***	−35.108 [1]***
Y_t^2	−2.829 [1]	−4.028 [1]	2008	−10.865 [1]	−4.705 [0]***	−35.028 [1]***
E_t	−0.482 [1]	−3.207 [1]	1995	−1.848 [1]	−3.272 [0]***	−40.543 [1]***
U_t	−2.343 [1]	−6.774 [8]***	1999	−1.433 [1]	−0.695 [0]	−7.632 [1]

Source: own calculation.

The results of ADF-GLS and Schmidt-Phillips tests indicate that all analyzed variables, except the urbanization ratio, are first order integrated. The Zivot-Andrews test provides grounds for concluding that in case of majority of variables the structural change does not occur, the only exception being the time series of urbanization level for Finland, France and the United Kingdom. The Zivot-Andrews test indicates an occurrence of the structural break in urbanization level for Finland in 1986 at significance level 0.1, for France in 1975 and for the United Kingdom in 1999 at significance level 0.01.

The first stage of the analysis was to estimate the relationship between CO_2 emission and economic growth in the context of the EKC hypothesis and verifying the occurrence of the cointegration effect. Parameters of the EKC model (1) were estimated with Fully Modified Ordinary Least Squares (FMOLS) method and then in accordance with the Engle-Granger and Phillips-Ouliaris approach (3)–(6), residuals of the long-run equation were tested for stationarity. Simultaneously, the correctness of specification of the long-run equilibrium equation (1) was verified due to the stability of its parameters and the absence of spurious time trends, following the Hansen and Park approach (comp. Table 5–6).

Table 5. Estimated parameters of the EKC model (1)

Country	Const.	lnY	$(\ln Y)^2$	Turning Points (date)	Signs of the EKC parameters	Adjusted R-squared
Finland	−81.433*** [0.000]	15.511*** [0.000]	−0.731*** [0.000]	40515.47 US$ (2006)	appropriate	0.974
France	−51.474*** [0.001]	9.489*** [0.002]	−0.430*** [0.005]	61927.58 US$	appropriate	0.960
Spain	78.803*** [0.000]	−17.149*** [0.000]	0.933*** [0.000]	—	inappropriate	0.819
United Kingdom	−65.313*** [0.000]	12.405*** [0.000]	−0.583*** [0.000]	41728.37 US$ (2007)	appropriate	0.950

Note: (***), (**), (*) indicate significance at 1%, 5% and 10% level; p-value in brackets.

Source: own calculation.

In order to exclude the occurrence of spurious regression effect it is necessary first to investigate the cointegrating behaviour of analyzed variables and only after that conclusions about the acceptance or rejection of the EKC hypothesis may be drawn.

Table 6. Results of cointegration test for the EKC model (1)

Country	Engle-Granger test	Phillips-Ouliaris test	Hansen parameter instability test	Park added variables test (linear trend)
Finland	−3.820** [0.048]	−3.973** [0.041]	0.175 [p > 0.2]	1.970 [0.160]
France	−1.423 [0.913]	−1.814 [0.809]	1.013*** [p < 0.01]	7.071*** [0.008]
Spain	−1.643 [0.862]	−1.754 [0.829]	0.604** [0.026]	0.844 [0.358]
United Kingdom	−1.885 [0.783]	−2.350 [0.572]	0.932*** [p < 0.01]	0.556 [0.456]

Note: (***), (**), (*) indicate significance at 1%, 5% and 10. The lag length is selected such that the BIC is minimized. p-value in brackets.

Source: own calculation.

The results of the Engle-Granger and Phillips-Ouliaris tests are similar for France, Spain and the United Kingdom. Namely, there is no reason to reject the null hypothesis about non-stationarity of residuals series that are obtained from the EKC model (1) at 0.1 significance level. These results confirm the lack of cointegrating relationship between carbon dioxide emissions level per capita and real GDP per capita. In other words, model (1) can not be used to describe the long-run equilibrium path between air pollutant emissions and income for transport sector in France, Spain and the United Kingdom. The Hansen test rejects the null hypothesis that the series are cointegrated at conventional levels, which is consistent with results of previous tests. In the case of Spain and the United Kingdom, the Park's test results give no reason to reject the null hypothesis of cointegration, what is in direct contrast to the results for the Engle-Granger, Phillips-Ouliarias and Hansen tests. Only for Finland, the results of all conducted tests confirm the existence of the cointegrating relationship between transport carbon dioxide emissions and income.

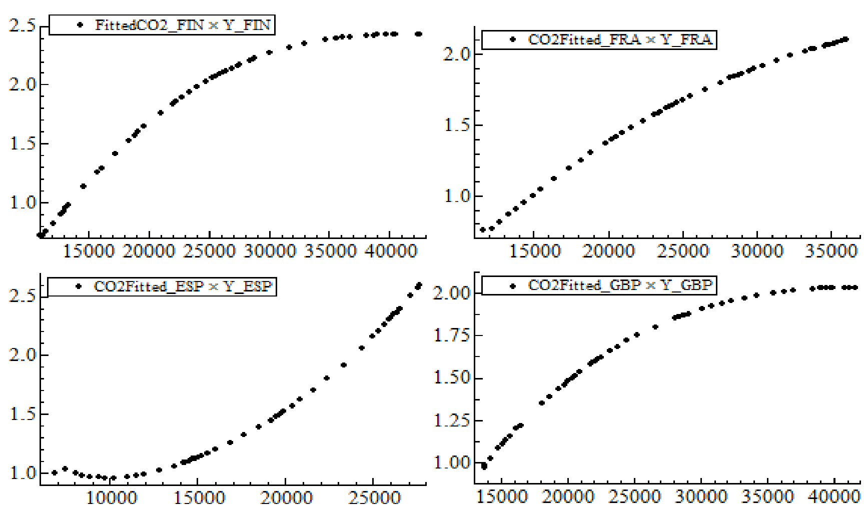

Fig. 3. Fitted values for the estimated EKC relation for CO_2 emissions in Finland, France (upper panel), in Spain and the United Kingdom (lower panel)

Source: own elaboration.

Analyzing Figure 3, one may notice that characteristic inverted U--shaped curve occurs only for Finland and the United Kingdom. Moreover, in both cases the estimated threshold values of income are placed in the sample range of real GDP per capita, namely the turning points are located at US$ 40515.47 (Finland, in 2006) and at US$ 41728.37 (the United Kingdom, in 2007). It is worth noting that the estimated value of the turning point for France (61927.58 US$) has not been reached so far and the shape of the EKC plot may suggest that this value may be realized in the future.

Summing up this stage of studies, it is worth stressing that the EKC hypothesis verification is unfavourable for France and the United Kingdom because in both cases residuals from the equation (1) are not stationary. This makes it impossible to use this model for further analysis of the pollutant-income relationship in France and the United Kingdom due to the possibility of spurious regression effect occurrence. Similarly, there are two reasons for the rejection of the EKC hypothesis for Spain. Firstly, residuals of the EKC model (1) are not stationary as one takes into consideration the results of the Engle-Granger and Phillips-Ouliaris tests. Secondly, the signs of parameters in the long-term equation are not consistent with theoretical assumptions, according to which the long-term dependence between environment degradation and economic growth is of an inverted U shape [4]. Such shape can be observed in case of Finland and the United Kingdom (comp. Fig. 3), but only in case of Finland the EKC hypothesis is additionally confirmed by the results of the Engle-Granger, Phillips-Ouliaris, Hansen and Park tests (stationarity of residuals from the EKC model, lack of remaining stochastic trend in the residuals, stability of model parameters, significance of parameter estimates and their signs: $\alpha_0 < 0$, $\alpha_1 > 0$ and $\alpha_2 < 0$).

The next step of the analysis is connected with the examination of the modified EKC model (2) which concerns the inclusion of the additional variables in order to investigate the complex nature of the relationship between environmental degradation and economic growth. In this work three additional exogenous variables are included into the EKC model (2), namely road transport energy consumption, urbanization ratio and fuel prices what enable to verify the impact of socio-economic factors on CO_2 emissions in transport sector. In the first specification (I) only road transport energy consumption is added, in the second specification (II) both energy consumption and fuel prices are included into the EKC model (2) and in the third specification (III) simultaneously energy consumption, fuel prices and urbanization ratio are involved (2). Estimates of parameters for each of the three modified EKC models are shown in Table 7.

Table 7. Estimated parameters for the EKC model (2)

Model	**Const.**	**lnY**	**(lnY)^2**	**lnE**	**lnFP**	**lnU**	**Signs of the EKC parameters**	**Adjusted R-squared**
Finland I	−8.090 [0.258]	0.689 [0.633]	-0.029 [0.677]	0.739*** [0.000]	—	—	appropriate	0.997
Finland II	−8.525 [0.237]	0.836 [0.565]	-0.031 [0.649]	0.624*** [0.000]	−0.074*** [0.000]	—	appropriate	0.998
Finland III	−6.030 [0.274]	0.106 [0.924]	-0.0014 [0.979]	0.630*** [0.000]	−0.052*** [0.005]	0.408** [0.038]	appropriate	0.998

Table 7. Estimated parameters… (cont.)

Model	Const.	lnY	(lnY)2	lnE	lnFP	lnU	Signs of the EKC parameters	Adjusted R-squared
France I	87.161*** [0.000]	−18.404*** [0.000]	0.877*** [0.000]	1.550*** [0.000]	—	—	inappropriate	0.990
France II	84.801*** [0.001]	−17.929*** [0.001]	0.856*** [0.001]	1.514*** [0.000]	−0.002 [0.957]	—	inappropriate	0.990
France III	19.838* [0.055]	−2.787 [0.193]	0.149 [0.138]	1.035*** [0.000]	0.040** [0.023]	−3.003*** [0.000]	inappropriate	0.998
Spain I	92.740*** [0.000]	−19.610*** [0.000]	0.975*** [0.000]	1.024*** [0.000]	—	—	inappropriate	0.981
Spain II	91.616*** [0.000]	−19.380*** [0.000]	0.965*** [0.000]	0.999*** [0.000]	−0.032 [0.545]	—	inappropriate	0.981
Spain III	90.546*** [0.000]	−18.952*** [0.000]	0.943*** [0.000]	1.035*** [0.000]	−0.039 [0.491]	−0.289 [0.745]	inappropriate	0.981
UK I	−7.504 [0.653]	0.731 [0.828]	−0.030 [0.851]	0.594*** [0.000]	—	—	appropriate	0.972
UK II	−30.280* [0.070]	5.423 [0.107]	−0.244 [0.124]	0.167 [0.388]	−0.126*** [0.004]	—	appropriate	0.976
UK III	−30.775* [0.058]	3.696 [0.262]	−0.170 [0.273]	0.328* [0.098]	−0.158*** [0.000]	2.144 [0.112]	appropriate	0.977

Source: own calculation.

As it can be observed while analyzing the results in Table 7, the inclusion of three additional variables into the EKC model changes the estimation results. Comparing the signs and significance levels of the coefficients related to income and squared income in both long-run equilibrium models one may notice the essential differences among them. In case of France, the inverted U-shaped relationship between CO_2 emissions and income (observed in the EKC model (1)) is changed into the U-shaped one. Estimates of parameters assigned to income and squared income are statistically insignificant in the EKC model (2) for Finland and the United Kingdom, what is in direct contrast to the results for the EKC model (1). Only for Spain, the FMOLS estimation results for the second specification of the long-run equilibrium model are robust to the inclusion of three additional variables, namely road transport energy consumption, fuel prices and urbanization ratio. It is worth stressing that the elasticity parameter of transport CO_2 emissions related to road transport energy consumption is positive and statistical significant at 1% level for each country. The results in Table 7 shows that a 1% increase in road transport related energy consumption per capita increases carbon dioxide emissions per capita, derived from transportation activity, approximately by 0.739% in Finland, by 1.55% in France, by 1.024% in Spain and by 0.594% in the United Kingdom, under ceteris paribus assumption. Additionally, it is noticeable that transport related carbon dioxide emissions is negatively influenced by gasoline prices in each analyzed country, what means that the increase in gasoline prices may reduce the negative impact of transportation activity on environment through the reduction of transport energy use and the improvement of energy efficiency of transport sector. However, the price-result is statistically significant only for Finland and the United Kingdom and it may be omitted considered its weak environmental impact. Namely, a 1% increase in gasoline prices decreases carbon dioxide emissions per capita, derived from transportation activity, on average by 0.074% in Finland and by 0.126% in the United Kingdom. Pablo-Romero et all. (2017) show that liquid fuels prices growth has not direct impact on road transport energy use by households in the chosen EU countries. Moreover, they stress that productive transport energy use is more sensitive to fuels prices variation, due to intensive development of international transport of imported goods. It is caused by a shift in emissions-intensive production from developed countries with stringent environmental regulatory regimes to developing countries with weak environmental regulations. Additionally, the coefficient related to urbanization ratio is positive and statistically significant at 0.05 level only for Finland. The positive value may relate to an increase in carbon dioxide emissions level derived from road transport when urbanization process runs intensively. In case of France, parameter assigned to urbanization ratio is also statistically significant at 0.01 level, but its sign is negative. However, this result should be treated with caution because of the quality of the estimated EKC model for France and the results of Zivot-Andrews test. It is worth noting that the removal of urbanization indicator from the EKC model (2) does not significantly affect the signs and values of parameters related to income and squared income.

Table 8. Results of cointegration test for the EKC model (2)

Country	Engle--Granger test	Phillips--Ouliaris test	Hansen parameter instability test	Park added variables test (linear trend)
Finland I	−1.660 [0.941]	−1.806 [0.9158]	1.406^{***} [$p < 0.01$]	1.333 [0.248]
Finland II	-4.067^{*} [0.095]	-4.499^{*} [0.089]	0.251 [$p > 0.2$]	0.016 [0.899]
Finland III	−3.769 [0.394]	−3.882 [0.345]	0.445 [$p > 0.2$]	8.986^{***} [0.003]
France I	−2.204 [0.806]	−2.448 [0.707]	0.576 [0.162]	2.750^{*} [0.097]
France II	−2.121 [0.922]	−2.430 [0.845]	0.535 [$p > 0.2$]	4.503^{**} [0.034]

Table 8. Results of cointegration test… (cd.)

Country	Engle--Granger test	Phillips--Ouliaris test	Hansen parameter instability test	Park added variables test (linear trend)
France III	−3.441 [0.549]	0.549 [0.442]	0.304 [p > 0.2]	0.147 [0.702]
Spain I	−5.280*** [0.005]	−4.445** [0.039]	0.857* [0.045]	3.001* [0.083]
Spain II	−5.352** [0.012]	−4.454* [0.082]	0.886* [0.062]	3.926** [0.048]
Spain III	−5.577** [0.017]	−4.522 [0.134]	1.034** [0.033]	7.853*** [0.005]
United Kingdom I	−4.011* [0.094]	−3.923* [0.099]	0.994** [0.025]	0.460 [0.498]
United Kingdom II	−3.848 [0.232]	−3.996 [0.184]	1.591*** [p < 0.01]	0.474 [0.491]
United Kingdom III	−4.204 [0.224]	−4.089 [0.263]	1.987*** [p < 0.01]	13.413*** [0.000]

Note: (***), (**), (*) indicate significance at 1%, 5% and 10. The lag length is selected such that the BIC is minimized. p-value in brackets.

Source: own calculation.

The last stage of the analysis consists in verifying the occurrence of the cointegration effect between carbon dioxide emissions and the set of explanatory variables, namely real GDP, road transport related energy consumption and urbanization ratio (see Table 8). The results of conducted tests are rather inconclusive for the majority of estimated models. Residual-based cointegration tests point at the rejection of the null hypothesis about the lack of cointegrating relationship for transport sector in Finland (only the second model), in Spain (all three models) and in the United Kingdom (only the first model). Results of Hansen parameter stability test confirm the existence of the long-run equilibrium relationship in case of Finland (the second and third model) and France (all three models). In turn, results of Park added variables test let to reject the null hypothesis about the lack of cointegrating relationship for the transport sector in Finland (only the third models), in France (the first and second models), in Spain (all three models) and in the United Kingdom (only the third model).

5. Conclusion

The paper presents mutual conditionings occurring among the demand for transport services, economic growth, urbanization, energy consumption and carbon dioxide emission by transport sector. In accordance with the environmental Kuznets curve hypothesis after a certain level of economic growth is achieved a decoupling between CO_2 emissions and GDP can be observed, which means that CO_2 emission growth is slower than economic growth. The EKC hypothesis was verified for the transport sector in four selected countries of the EU of different level of economic growth using the methodology proposed by Engle and Granger (1987), Phillips and Ouliaris (1990), Hansen (1992) and Park (1992). The results of the initial research presented in this paper show that the inverted U-shape can be observed in case of Finland and the United Kingdom, but only in case of Finland the EKC hypothesis is confirmed by the results of the conducted cointegration tests. Moreover, the FMOLS estimation results show the necessity to extend the traditional EKC model through the inclusion of road transport related energy consumption variable. It is also worth stressing that the complex nature of this relationship requires the use of more sophisticated econometric tools. Therefore, the future studies will incorporate regime-switching models in order to investigate the existence of cointegration relationship between air pollutant emissions derived from road transport, income and energy consumption.

The author also indicates at the instruments of environmental management which may contribute to limiting to some extent CO_2 emission in the transport sector. It is worth noting that econometric tools will provide vital information with regard to selecting proper instruments of climate policy, individually adjusted for each of the countries, limiting the emission of pollution in the transport sector. Econometric tools enable the identification of socio-economic factors affecting the level of air pollutant emissions in transport sector. Such knowledge can be used to formulate the ecological strategies by transport companies or the authorities of urban agglomerations, that ought to be in line with the changing EU legislation in this area.

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Narzędzia ekonometryczne wspomagające proces zarządzania środowiskowego w sektorze transportu

Synopsis: Emisja zanieczyszczeń powietrza generowana przez transport drogowy jest produktem ubocznym emisji spalin, które są wytwarzane w procesie spalania paliwa. Wzrost ruchu drogowego, spowodowany między innymi przez takie czynniki, jak wzrost gospodarczy, procesy urbanizacji, zmiana standardu życia, poprawa infrastruktury drogowej, prowadzi do wzrostu zużycia energii w sektorze transportu i pogorszenia jakości powietrza. Decydenci odpowiedzialni za rozwój transportu drogowego powinni coraz częściej wykorzystywać instrumenty zarządzania środowiskowego w celu poprawy jakości powietrza i ograniczenia emisji zanieczyszczeń, szczególnie na obszarach miejskich. Skuteczność tych instrumentów może być wzmocniona poprzez wykorzystanie narzędzi ekonometrycznych, za pomocą których można zidentyfikować determinanty emisji zanieczyszczeń powietrza w sektorze transportu. Stąd w niniejszym opracowaniu sprawdzane jest istnienie długoterminowej relacji równowagi pomiędzy emisją dwutlenku węgla w sektorze transportu a PKB, zużyciem energii w tym sektorze, cenami paliw, wskaźnikiem urbanizacji dla wybranych krajów UE. Tło badań empirycznych stanowi hipoteza środowiskowej krzywej Kuznetsa (EKC). Hipoteza ta została zweryfikowana za pomocą różnych testów kointegracji: testu Hansena na stabilność parametrów modelu, testu dodanych zmiennych Parka, testów Engla-Grangera oraz Phillipsa-Ouliarisa weryfikujących stacjonarność reszt modelu.

Słowa kluczowe: sektor transportu, emisja dwutlenku węgla, zarządzanie środowiskowe, narzędzia ekonometryczne.