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Article

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Assessment of the Effect of Environmental Taxes on Environmental Protection

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Abstract

The article analyses the effect of environmental taxes on environmental protection. The research covers all European Union member states, the United States of America, Japan and People's Republic of China, Norway and Turkey. Method for assessment of the regression tendencies of endogenous indicators has been chosen for the research. Research period: 1994 – 2015. Research results: environmental tax effect is stronger in countries having slower economic and tax growth, but more rapid development of renewable energy production technologies; the role of environmental taxes is more prominent where the level of natural energy resources is maintained at the expense of renewable energy use; ecological taxation encourages development and implementation of technologies that mitigate pollution and creation of new jobs; environmental taxes are directly related to humans' ecological quality of life.

Keywords: *environmental taxes, environmental protection, assessment of the effect*

JEL Classification: H21, H71, C54

Introduction

Climate change related agreement between the countries during Paris Climate Change Conference 2015 has maintained the balance, and its roadmap is aimed at limiting global warming to well below 2°C. According to Carole Dieschbourg, the Minister of Environment of Luxembourg, the agreement is the roadmap for a better, fairer and more sustainable world (Dieschbourg, 2015).

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A number of countries have already undertaken certain climate change and environmental pollution mitigation measures after environmental pollution reached the level that called for real attention back in the 60s of the last century. Environmental taxes regulating the interplay between the economy and environment comprise one of such measures. Revenues collected from these taxes are allocated to promotion of sustainable economy based on nature conservation, greener production. The importance of environmental taxes is defined by their ability to implement the goals of environmental pollution reduction. Researchers however seem to not have found a consensus towards this aspect. Castiglione et al. (2014a) have emphasized that application of environmental taxes can be considered as a controversial policy measure.

However, there is evidence of positive effect of environmental taxes in particular in terms of pollution reduction, in economically developed countries. On the other hand, environmental taxes have been claimed to diminish the results of economic activity because of distorting effect on production and consumption. Although scientific literature provides rather comprehensive analysis of the effect of environmental taxation on environmental protection and economy, the works are usually limited to mere comparison of revenues from environmental taxes to the limited indicators of environmental pollution, such as national CO_2 or GHG (greenhouse gas) emissions. However, relatively few discussions have been held on the method for assessment and identification of the effect of environmental taxes on the indicators of environmental pollution, as well as main factors to be analysed in assessing effect of environmental taxes and the rationale behind them (Castiglione et al., 2014a; Morley, 2012; Skjelvik, Bruvoll and Ibenholt, 2011; Im and Wonhyuk, 2010).

Therefore, the main research problem is to define: which factors should be used for assessment of the effect of environmental taxes on environmental protection, and the degree of their effect? The main objectives of the paper are:

- analysis of the previous research works followed by identification of the factors that have effect on reduction of environmental pollution and development of their research methodology;
- determination and assessment of the effect of environmental taxes on environmental protection in EU member states and other countries.

Review of Scientific Literature

Analysis of previous empirical studies dealing with assessment of environmental tax effect on environmental pollution (Castiglione et al., 2014a; Abdullah and Morley, 2014; Kurtinaitytė-Venediktovienė, Pereira and Černiauskas, 2014;

Tsakas and Katharaki, 2014; Kalinichenko, 2014; Castiglione et al., 2014b; Krass and Nedorezov, 2013; Mascu, 2013; Nagy, 2013; Morley, 2012; Piciu and Trica, 2012; Heine, Norregaard and Parry, 2012; Skjelvik, Bruvoll and Ibenholt, 2011; Opulskyte, 2011; Parry, 2011; Valles-Gimenez, Zarate-Marco and Trueba--Cortes, 2010; Im and Wonhyuk, 2010; Klingelhofer, 2010; Scasny et al., 2009; Lazdina, 2008; Barker et al., 2007) has shown that although majority of the authors assess the effect of environmental taxes on environmental protection using the multidimensional regression model, their approach to selection of dependent and independent variables quite differs.

Morley (2012) has conducted empirical study for assessment of the effect of environmental taxes on environmental protection dealing with the issue of global warming by verifying the effect of environmental taxes on air pollution and energy consumption level in the EU. The analysis is based on an econometric model employing the factors used in conventional approach towards pollution and energy consumption proposed by Grossman and Krueger (1995). According to Morley (2012), GHG amount should be considered as a dependent variable. Im and Wonhyuk (2010) share the same approach as Morley (2012), namely, that environmental performance measured as GHG amount should be considered as a dependent variable. Environmental performance is essentially related to enhancement of environmental quality; therefore, pollution reduction has positive effect on environmental performance. In assessment of enhancement of the overall environmental quality, the authors place the main focus on air pollution factors and, as a result, use GHG emissions as the main environmental performance indicator which encompasses CO_2, methane (NH4) and nitrous oxide (NO_2) emissions. All GHG emissions are assessed based on Global Warming Potential (GWP). For example, the GWP for methane over 100 years is 34 and for nitrous oxide –298, for CO_2 – 1. This means that emissions of 1 million metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 34 and 298 million metric tonnes of carbon dioxide. Meanwhile, Castiglione et al. (2014a) argue that environmental tax revenues should be used as a dependent variable, as they also reflect to the environmental policy.

Hence, there are researchers who advocate application of environmental taxes as a dependent variable for identification of indicators that have the greatest effect on variation of these taxes, while other researchers argue that the environmental protection indicator should be used as a dependent variable, while environmental taxes should be an independent variable, claiming that this is the only way to determine how environmental taxes effect on reduction of environmental pollution. In our opinion, the effect of environmental taxes on environmental protection indicators should be assessed by taking an integrated approach. Morley

(2012), Im and Wonhyuk (2010), Jackson (2009), aiming to assess the effect of environmental taxes on environmental protection, propose taking GHG emission amount, one of the key pollution indicators used worldwide, as a dependent variable. GHG amount covers CO_2, methane (NH_4) and nitrogen oxide (N_2O) according to the base established by Kyoto Protocol.

In development of methodology, another factor – scope of investments into environmental protection – has been added to the list of factors analysed by the researchers. This factor as the key factor has been emphasized by Morley (2012). On one hand, the variable of investments into environmental protection would be expected to have a negative effect, as increasing investments would provide easier access to more advanced, energy intensive production technologies. On the other hand, with increasing emissions into the atmosphere, investments into environmental protection would need to be increased to a certain breaking point, at which the amount of pollutants starts to decline.

According to various researchers, the key factor in assessment of the effect of environmental taxes on environmental protection is the share of environmental tax revenues in the total tax revenues, even though efficiency of environmental taxes is considered to be negative due to exemptions that apply to energy intensive industries (Im and Wonhyuk, 2010). Morley (2012) argues that effectiveness of these taxes reduces because of exemptions proposed for certain industries with the ultimate goal of maintaining international competitiveness.

Population growth is another important factor. Population growth nationwide leads to increasing consumption, with the resulting increase in environmental pollution. Every resident is a consumer, which means that growth in the number of consumers is accompanied by increased electricity and heat consumption, generation of waste all of that leading to higher pollution. It is therefore important to assess the effect of variation in population density on environmental protection (Im and Wonhyuk, 2010).

GDP is the main indicator of the national economic growth at a certain moment. Nonetheless, the level of pollution varies depending on the growth rate characteristic of each country. OECD employs the concept of decoupling for assessment of national results of activity in environmental protection. It is important to distinguish between absolute and relative decoupling. Absolute decoupling refers to the situation characterised by stable or declining variables of environmental pollution in the context of growth of the national economy. Relative decoupling refers to pollution index rising at a rate lower than the GDP growth rate (Jackson, 2009). It would therefore be reasonable to analyse the GDP per capita as another important indicator of economic growth, as it may affect environmental performance considerably.

Previous studies have provided evidence that economic growth has direct influence on growth of CO_2 emission. It is still important to acknowledge that economic growth promotes the processes of industrialization and urbanization also leading to increased CO_2 emission levels. This is the result of increasing production and consumption promoted by growing economy, and higher level of atmospheric pollution is the consequence of such processes. It is therefore important to complement the model with annual industrial production sales growth rate reflecting production intensity. Table 1 summarizes the main variables proposed by the researchers to be included into the model for assessment of the effect of environmental taxes on environmental pollution.

Table 1

Variables for Assessment of Factors of Reduction of Environmental Pollution

Variable	Description	Unit of measure	Authors
Dependent variable			
Pollution index	GHG amount	thous. tons as CO_2 equivalent	Morley (2012); Abdullah and Morley (2014)
Independent variables			
GDP	GDP per capita	EUR	Im and Wonhyuk (2010); Morley (2012); Castiglione et al. (2014a; 2014b); Valles-Gimenez, Zarate-Marco and Trueba Cortes (2010); Abdullah and Morley (2014); Soderholm and Christiernsson (2008)
Investments	Investments into environmental protection	EUR	Castiglione et al. (2014a; 2014b); Kaufmann (2014); Soderholm and Christiernsson (2008)
Environmental taxes	Share of environmental taxes in overall taxes	%	Im and Wonhyuk (2010); Morley (2012); Soderholm and Christiernsson (2008)
Population	Population density in the country	People per sq. km	Morley (2012); Valles-Gimenez, Zarate-Marco and Trueba-Cortes (2010)
Economic growth	Annual GDP growth rate	%	Im and Wonhyuk (2010); Abdullah and Morley (2014)
Production	Annual industrial production sales growth rate	%	Im and Wonhyuk (2010)

Source: Created by authors'on the basis of Im and Wonhyuk (2010); Skjelvik, Bruvoll and Ibenholt (2011); Castiglione et al. (2014a); Morley (2012) data.

Methodology for Assessment of the Effect of Environmental Taxes on Environmental Pollution Indicators

The research covers all EU member states including the United Kingdom, and the world's largest countries: the United States of America, Japan and People's Republic of China, as well as Norway that has large natural energy resources at its disposal, and Turkey that serves as the geographical link between the Middle East and the European Union.

Purpose of the environmental taxes – mitigation of the state of natural environment by means of ecologization of economy. This political instrument could be construed as an investment that would pay back in some more distant future. The data of endogenous (effect) indicators should therefore be treated in view of the time shifts in assessment of the state of environment through the prism of environmental taxes. Experiments with the initial data series (endogenous in relation to exogenous) have shown that their regression trends have remained virtually the same for parallel data and for the data subject to one/two/three time shifts, in which case part of the data set is lost. Parallel method for assessment of the regression tendencies (cause-and-effect relationships) of endogenous indicators has been chosen for the study, as the overall dynamic tendency of endogenous indicators has later been found to interact with the overall tendency of development of exogenous indicators (regressors). Research period: 1994 – 2015 (certain reservations apply to individual countries due to lack of certain data). Data for the research have been drawn from the data bases of Global Footprint Network, Eurostat, OECD, World Bank. Eurostat and OECD use different currencies in their data of indicators expressed by value; hence, GDP in USD to GDP in EUR ratio has been applied to the long-period data. The calculations have been performed using MS Excel, Statistica, and SPSS software instruments.

Logarithmic regression ($\ln\hat{y} = \ln a + b\ln x$), which is the linear transformation of power function ($\hat{y} = a \cdot x^b$), has been applied for assessment of the cause-and-effect relationships between the environmental state and the processes influencing this state. The so-called „log-log" regression has been employed, as it secures statistically more valid results in almost all cases compared to other types of regression. F-criterion with the theoretical limit value equal to 4.35 at 95% probability, or 5% level of significance and the span of 22 years has been applied for validity assessment of the results. With the F value increase, the statistical validity increases as well, and probability *p* of the F-criterion, being the symbol of statistical significance, decreases. Obviously, not all countries have provided complete data, and the theoretical value of F-criterion has been subject to slight increase in view of the smaller sample. The causality level, or determination coefficient, has not been viewed as highly important in this work due to availability of F-criterion. It can be easily determined by using the F-criterion formula.

„Log-log" regression *b*-coefficient, present next to regressor *x*, carries the following meaning: endogenous indicator *y* changes by the percent of *b* value at one percent increase of regressor *x*. In other words, *b*-coefficient is the elasticity of an endogenous indicator in relation to changes of the regressor. Elasticity of an endogenous indicator, or regression tendency, or rate of change, at 1% growth of the regressor, are synonyms. Hence, the elasticity attribute and its synonyms are deemed as the effect indicator in this study.

For comparison of the effect variables distributed on the scales of different ranges, the linear scaling method, usually employed in the international practice, has been applied in this study. Despite the wide variety of data normalization or standardization methods, indexation method has been chosen for this study in view of its appropriateness where both positive and negative data series are subject to normalization. The index of elasticity indicator for the positive elasticity series has been calculated as follows: $I = (b - b_{min})/(b_{max} - b_{min})$. For negative series, the same ratio has been subtracted from one. Weighted index has been employed to generalization of the results. Weight of the index value is the share of its value in the total sum of the index series. Finally, the summative index of the effect indicator has been obtained by summing up the products of multiplication of the index series values and weights.

In the present study, the endogenous indicators, or dependent variables are, *primarily*, deemed to include the key characteristics of environmental state, such as the greenhouse emissions (GHG, in thous. *t* of CO_2 equivalent); CO_2 emissions comprising somewhat two thirds of the GHG emissions (CO_2. thous. *t*); ecological supply, or biocapacity (BC), and demand, or footprint (FP), representing the available and used natural resources converted into land area (in global hectares (*gha*). It shall further be accepted that CO_2 release into the environment is largely determined by the use of energy by households and industry, meaning that taxation of energy consumption in light of ongoing depletion of its natural resources gives impetus to development of innovative energy technologies and exploration of alternative and/or renewable energy sources. Moreover, renewable energy use is favourable to the environment, as it does not contribute to increase of CO_2 concentration in air. Hence, *second*, the indicators of maintenance of environmental (in this case – that of the natural resources) state shall be deemed to include the renewable energy use (REN, thous. *t* of oil equivalent) and to increase its share in the total energy consumption, the upward trend of which partially reflects the level of maintenance of natural energy resources and level of environmental protection.

Results of Study

Analysis of the processes occurring in the surrounding environment requires that cause-and-effect relationships between the environmental state and the processes acting on it are understood clearly, reliable indicators are available, and the ability to apply environmental measures is present.

T a b l e 2

Ecological Deficit/Reserve of the Countries

Country		1961 – 1964	1965 – 1968	1969 – 1972	1973 – 1976	1977 – 1980	1981 – 1984	1985 – 1988	1989 – 1992	1993 – 1996	1997 – 2000	2001 – 2004	2005 – 2008	2009 – 2012	2013 – ...
LU	Luxemburg	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪	▪▪▪▪▪
BE	Belgium	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪
US	United States	▪▪▪	▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪	▪▪▪
NL	Netherlands	▪▪	▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪
UK	Un.Kingdom	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
DE	Germany	▪▪▪	▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
JP	Japan	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
IT	Italy	▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
ES	Spain	▪	▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪	▪▪
CY	Cyprus	▪	▪	▪	▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪▪	▪▪▪	▪▪▪
DK	Denmark	▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪	▪
EL	Greece	▪	▪	▪	▪▪	▪▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪
FR	France	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪
PL	Poland	▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪▪
AT	Austria	▪	▪	▪	▪	▪	▪	▪	▪▪	▪▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪
CZ	Czech R.									▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪
SL	Slovenia									▪	▪▪	▪▪	▪▪▪	▪▪	▪▪
PT	Portugal	▪	▪	▪	▪	▪	▪	▪	▪▪	▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪	▪▪
HU	Hungary	▪	▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪	▪	▪	▪	▪	▪	▪
BG	Bulgaria	▪	▪	▪▪	▪▪	▪▪	▪▪	▪▪	▪	▪	▪	▪	▪	▪	▪
RO	Romania	▪	▪	▪	▪	▪▪	▪▪	▪▪	▪	▪	▪	▪	▪	▪	▫
CH	China	▫	▫	▪	▪	▪	▪	▪	▪	▪	▪	▪	▪	▪▪	▪▪
IE	Ireland	▫	▫	▪	▪	▪	▪	▪	▪	▪	▪▪	▪	▪▪	▪	▪
SK	Slovak R.									▪	▪	▪	▪▪	▪	▪
TU	Turkey	▫	▫	▫	▫	▫	▪	▪	▪	▪	▪	▪	▪	▪	▪
LT	Lithuania									▪	▪	▪	▪	▪	▪
HR	Croatia									▫	▪	▪	▪	▪	▪
NO	Norway	▫▫	▪	▪	▪	▪	▫	▫	▫▫	▫▫	▫▫	▫▫	▫	▫▫	▫▫
LV	Latvia									▫▫	▫▫	▫▫	▫	▫▫▫	▫▫▫
EE	Estonia									▫▫▫	▫▫▫	▫	▫	▫▫▫	▫▫▫
SE	Sweden	▫▫▫▫	▫▫▫▫	▫▫▫	▫▫▫	▫▫▫	▫▫▫▫	▫▫▫▫	▫▫▫▫	▫▫▫▫	▫▫▫	▫▫▫	▫▫▫	▫▫▫	▫▫▫
FI	Finland	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫	▫▫▫▫▫▫	▫▫▫▫

Source: Own processing.

Key environmental, economic and financial indicators from the long-term perspective of their development are primarily presented in order to reveal changes in the state of environment surrounding us (by application of the environmental measures) (Table 2 and Table 3). The window presented below features the symbolically „dark" area in the approximately 50-year span. „Dark" („▪▪▪") area symbolises ecological deficit expressed in the difference between the ecological demand, i.e. footprint (FP), and ecological supply, i.e. biocapacity (BC), and is measured in global hectares. The light patches in the window obviously symbolise the ecological reserve („▫▫▫").

Ecological Deficit/Reserve of the Countries

The more symbols comprise a single position, the greater is the deficit or reserve by global hectares of natural resources per capita: 7 ÷ 9 gha – „▪▪▪▪▪” or „▫▫▫▫▫▫“; 5 ÷ 7 gha – „▪▪▪▪“ or „▫▫▫▫“; 4 ÷ 5 gha – „▪▪▪“ or „▫▫▫“; 2 ÷ 4 gha – „▪▪“ or „▫▫“; 0 ÷ 2 gha – „▪“ or „▫“. Here, greater number of symbols reflects greater deficit or reserve by global hectares of natural resources per capita: 7 ÷ 9 gha – „▪▪▪▪▪“ or „▫▫▫▫▫▫“; 5 ÷ 7 gha – „▪▪▪▪“ or „▫▫▫▫“; 4 ÷ 5 gha – „▪▪▪“ or „▫▫▫“; 2 ÷ 4 gha – „▪▪“ or „▫▫“; 0 ÷ 2 gha – „▪“ or „▫“.

The highest natural potential in the period referred to was demonstrated by Finland and Sweden, followed by Estonia, Latvia, and Norway. Unfortunately, the third Baltic country Lithuania no longer had any ecological reserve. The smallest country of the European Union (Malta) had the highest deficit of natural potential, followed by Belgium, the United States of America, the Netherlands, and the United Kingdom. In general, the ecological situation did not see any particular changes since 1993. Sweden, Estonia, Latvia, and Norway succeeded in maintaining the same level of natural potential, some other countries – in slightly reducing the deficit, while Denmark managed to return to the level of 1961 – 1964.

The table below presents the environmental economic and financial indicators of 12 + 12 countries, analysed in the study by four intervals of the research period.

The main environmental and economic indicators analysed in Table 3 include GHG/capita, renewable energy consumption per capita (REN/capita); income from environmental taxes per capita (ET/capita); energy consumption per capita (EN/capita) and GDP/capita.

The order of presentation of the countries in the Table 3 has been determined by ranking. The upper and lower sections represent the highest and lowest ranking entries (period averages).

Economically more sound countries are on the top of the Table 2 by indicators 1, 3, 4 and 5, with Luxembourg placing on the top, and the bottom usually is predominated by the countries that joined the European Union at later stages (with certain exceptions), as well as Turkey, and the People’s Republic of China. Indicator 2 is not subject to the patterns listed here.

Closer look at the Table 2 reveals sometimes unexpected and sometimes obvious facts. For example, GHG per capita in Estonia, in contrast to the neighbouring Latvia, catches up with the leading countries – Luxembourg and the U.S. By renewable energy use, the Baltic countries rank among the top ten countries of the total sample. The bottom twelve countries, such as Portugal, Croatia, are ahead of the U.S. by higher environmental taxes per capita. It is also obvious that the volumes of energy consumed correlate to the level of economic development of the respective countries (with insignificant deviations).

Table 3

Main Indicators of the Research

1. GHG per capita, *t* of CO2 equivalent					2. REN per capita, *t* of oil equivalent					3. ET per capita, thous. USD					4. EN per capita, *t* of oil equivalent					5. GDP per capita, thous. USD				
Country	1994 – 1998	1999 – 2004	2005 – 2010	2011 – 2015	Country	1994 – 1998	1999 – 2004	2005 – 2010	2011 – 2015	Country	1994 – 1998	1999 – 2004	2005 – 2010	2011 – 2015	Country	1994 – 1998	1999 – 2004	2005 – 2010	2011 – 2015	Country	1994 – 1998	1999 – 2004	2005 – 2010	2011 – 2015
LU	25.9	25.3	26.8	21.3	NO	3.21	3.41	3.61	3.37	LU	1.40	1.58	2.59	2.45	LU	7.73	8.19	8.70	7.28	LU	49.1	57.3	100.0	111.4
US	24.3	24.4	22.7	20.8	SE	1.92	2.07	2.35	2.52	DK	1.54	1.82	2.57	2.40	US	7.80	7.89	7.50	6.91	NO	34.6	44.0	81.9	95.2
EE	21.2	14.0	15.7	16.5	FI	1.68	2.00	2.20	2.43	NO	1.19	1.29	2.06	2.17	FI	6.06	6.65	6.74	6.21	DK	33.4	35.9	56.7	59.4
IE	18.8	17.6	15.6	13.0	AT	0.86	0.93	1.14	1.33	NL	0.90	1.06	1.75	1.69	NO	5.41	5.82	6.29	5.88	SE	29.7	32.7	49.5	57.3
CZ	14.6	15.1	14.1	12.7	EE	0.60	0.70	0.82	1.10	FI	0.76	0.90	1.26	1.47	SE	5.73	5.67	5.40	5.15	IE	20.6	33.9	54.7	54.0
FI	15.7	16.0	15.3	11.9	DK	0.30	0.42	0.64	0.86	AT	0.73	0.90	1.32	1.46	BE	5.42	5.58	5.43	4.86	US	30.3	38.1	47.1	53.0
NL	15.1	13.7	12.7	11.6	LV	0.59	0.63	0.73	0.85	SE	0.86	0.89	1.29	1.37	NL	4.80	4.88	4.90	4.49	NL	27.2	30.8	49.4	50.2
DE	13.7	12.4	11.8	11.5	SL	0.35	0.48	0.58	0.71	IT	0.72	0.61	1.00	1.32	EE	3.82	3.58	3.97	4.36	AT	27.9	28.6	45.2	49.0
NO	16.5	16.0	14.7	11.4	LT	0.28	0.43	0.51	0.63	IE	0.60	0.82	1.27	1.19	CZ	4.08	4.14	4.33	3.98	FI	24.6	28.8	45.9	48.0
BE	14.7	13.9	12.6	11.1	HR	0.54	0.53	0.57	0.62	UK	0.63	0.79	0.98	1.05	AT	3.47	3.78	4.01	3.86	BE	26.2	27.2	43.0	45.3
JP	11.2	11.1	10.9	10.9	PT	0.49	0.48	0.55	0.60	BE	0.69	0.69	0.98	0.99	DE	4.17	4.12	4.02	3.86	DE	28.8	27.3	40.4	45.3
PL	11.2	10.2	11.0	10.5	US	0.35	0.41	0.50	0.60	DE	0.63	0.66	0.90	0.95	FR	4.04	4.22	4.10	3.77	UK	24.1	31.1	43.1	43.1
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
LT	8.04	6.33	7.85	8.01	RO	0.24	0.27	0.37	0.38	PT	0.38	0.40	0.57	0.49	PL	2.57	2.35	2.52	2.55	CZ	5.85	8.05	18.18	19.73
IT	8.96	9.60	9.02	7.52	CH	0.26	0.28	0.31	0.37	HR	...	0.31	0.47	0.47	BG	2.59	2.38	2.56	2.48	EE	3.38	5.66	14.49	18.18
FR	9.36	9.13	8.44	7.31	SK	0.13	0.17	0.27	0.35	US	0.31	0.35	0.38	0.39	LT	2.47	2.45	2.72	2.40	SK	4.88	7.10	15.44	17.67
ES	8.07	9.46	8.96	7.23	EL	0.18	0.19	0.23	0.33	TU	0.07	0.14	0.33	0.39	HU	2.50	2.52	2.63	2.38	LT	2.51	4.37	11.33	15.04
HR	5.54	6.35	7.11	7.03	PL	0.16	0.17	0.20	0.29	HU	0.13	0.19	0.38	0.37	EL	2.23	2.58	2.68	2.25	LV	2.52	4.26	11.84	14.39
PT	7.05	8.39	7.65	6.54	HU	0.13	0.13	0.18	0.24	LV	0.04	0.10	0.26	0.37	CH	0.86	1.01	1.66	2.19	PL	3.87	5.24	11.07	13.55
CY	7.92	8.43	8.18	6.42	NL	0.07	0.09	0.18	0.24	SK	0.08	0.12	0.29	0.32	LV	1.84	1.77	2.10	2.15	HU	4.50	6.66	13.01	13.40
SE	9.46	8.83	7.73	6.19	IE	0.06	0.08	0.13	0.22	PL	0.07	0.11	0.23	0.27	PT	2.03	2.42	2.36	2.09	HR	5.10	6.42	13.11	13.28
HU	7.63	7.49	7.08	6.14	TU	0.24	0.21	0.19	0.19	LT	0.05	0.12	0.21	0.25	HR	1.78	2.02	2.19	1.99	TU	3.19	4.34	9.30	11.74
LV	7.28	5.39	6.44	6.14	UK	0.04	0.04	0.08	0.18	BG	0.02	0.06	0.17	0.20	CY	2.14	2.22	2.26	1.83	RO	1.62	2.25	7.53	9.26
RO	7.47	6.19	6.42	6.03	JP	0.15	0.16	0.16	0.18	RO	0.04	0.06	0.15	0.20	RO	1.97	1.71	1.83	1.66	BG	1.40	2.19	5.89	7.54
TU	4.60	4.84	5.61	5.94	CY	0.06	0.07	0.11	0.16	CH	...	0.01	0.03	0.09	TU	1.10	1.16	1.38	1.58	CH	0.68	1.14	3.08	6.97

Source: Own processing.

In general, it could be claimed that, except for certain individual cases, the GHG emissions tended to reduce; renewable energy use, income from environmental taxes – to increase; and the total energy consumption – to decrease.

In addressing the main research problem, it is necessary to assess of the links between the endogenous indicators and the environmental taxes. Various potentially and logically reasonable combinations of indicators have been assessed at the subsequent stage of the study by employing the „log-log" instrument. Namely, experiments with data of absolute, relative, and cumulative year-by-year indicators have been conducted.

Attempts have been made to employ the population size, number of people in employment, GDP, labour efficiency, energy consumption, fossil energy resource use, forest area as the denominator of the relative values. It should be emphasized that considerable number of the attempts have failed as the regression tendencies have been found to be statistically insignificant for the majority of the sample countries.

Overlapping variants have also been rejected. For example, elasticity of GHG and CO_2 emissions in relation to the environmental taxes could be claimed to not differ in any aspect. The same could be applied to the absolute and relative indicators.

Eventually, two groups of indicators have been found to be reasonable in the context of regression. The first group – relative indicators – has been found to cover FP, GHG and REN, where GDP and the share of renewable energy use in the total energy consumption (REN%) are employed as the denominator. The second group – absolute indicators – is comprised of the same endogenous indicators, the initial data of which have been subject to year-by-year cumulation (tagged „*" in Table 4).

It should be noted that the study deals with effect of environmental taxes (ET) on the environment. Therefore, tax revenues per capita (ET/capita) has been employed as the regressor in the first group of indicators, while the value of year--by-year accrued taxes has been used for the same purpose in relation to the second group of indicators. As already mentioned, the effect analysed by the present work and expressed in the elasticity of endogenous indicators in relation to the regressor is their growth/reduction in percentage in response to one percent growth of the regressor.

Table 4 presents the value of effect of environmental taxes in three forms: percentage change (Elasticity), weighted change (Index of Elasticity), and the overall weighted change (Weighted Index). The latter reflects the overall multi-criteria effect by its value according to the normalised scale (0 ÷ 1).

T a b l e 4

Elasticity of Environmental State Associated with Change in Environmental Tax Revenues

Country	**Elasticity% of**							**Index of an elasticity**							**Weighted**	**Country**
	FP	GHG	REN	REN%	FP *	GHG*	REN*	FP	GHG	REN	REN%	FP *	GHG*	REN*	Index	
AT	–0.78	–0.87	–0.38	0.33	0.86	0.85	0.89	0.14	0.20	0.22	0.09	0.76	0.78	0.59	**1.00**	**US**
BE	–0.72	–1.62	–1.62	3.00	0.93	0.87	1.30	0.12	0.54	1.00	1.00	0.86	0.81	0.98	**0.91**	**BE**
BG	–0.72	–0.76	–0.23	0.54	0.61	0.58	0.90	0.12	0.15	0.13	0.16	0.41	0.44	0.59	**0.76**	**DE**
CH	–0.47	–0.41	–0.58	0.18	0.31	0.33	0.27	0.00	0.00	0.35	0.04	0.00	0.11	0.00	**0.61**	**UK**
CY	–0.84	–0.85	–0.02	0.79	0.80	0.80	1.11	0.17	0.19	0.00	0.25	0.68	0.72	0.79	**0.50**	**NO**
CZ	–0.90	–1.02	–0.36	0.55	0.74	0.71	0.84	0.20	0.27	0.22	0.17	0.60	0.60	0.54	**0.47**	**JP**
DE	–1.15	–1.31	–1.37	2.57	0.91	0.89	1.33	0.31	0.40	0.84	0.86	0.83	0.83	1.00	**0.41**	**PT**
DK	–1.37	–1.56	–0.30	1.56	0.83	0.78	1.06	0.41	0.51	0.18	0.51	0.71	0.68	0.75	**0.39**	**DK**
EE	–0.90	–0.69	–0.39	0.68	0.49	0.24	0.59	0.20	0.12	0.23	0.21	0.25	0.00	0.31	**0.39**	**FR**
EL	–1.24	–1.12	–0.29	0.75	1.00	0.99	1.03	0.35	0.32	0.17	0.24	0.96	0.96	0.72	**0.38**	**IT**
ES	–1.33	–1.31	–0.59	0.58	0.90	0.90	0.94	0.39	0.40	0.36	0.18	0.82	0.84	0.63	**0.38**	**EL**
FI	–1.13	–1.30	–0.59	0.40	0.83	0.82	0.93	0.30	0.40	0.35	0.11	0.73	0.75	0.62	**0.38**	**SE**
FR	–1.01	–1.52	–0.89	0.37	1.03	0.90	0.90	0.25	0.49	0.54	0.11	1.00	0.84	0.59	**0.35**	**LU**
HR	–1.12	–1.04	–1.00	0.75	0.35	0.32	0.30	0.30	0.28	0.61	0.24	0.06	0.10	0.03	**0.35**	**NL**
HU	–1.06	–1.15	–0.60	0.42	0.76	0.74	0.81	0.27	0.33	0.36	0.12	0.62	0.63	0.51	**0.34**	**IE**
IE	–1.49	–1.60	–0.11	1.22	0.78	0.75	0.98	0.47	0.53	0.05	0.39	0.65	0.65	0.67	**0.34**	**ES**
IT	–0.81	–0.82	–0.61	1.31	0.94	0.94	1.15	0.16	0.18	0.37	0.43	0.88	0.90	0.83	**0.31**	**SL**
JP	–1.04	–0.95	–1.26	0.12	0.99	1.02	1.06	0.26	0.24	0.78	0.02	0.95	1.00	0.75	**0.27**	**FI**
LT	–0.80	–1.09	–0.63	0.43	0.73	0.60	0.81	0.15	0.30	0.38	0.13	0.58	0.46	0.51	**0.23**	**CY**
LU	–1.20	–1.19	–1.17	0.08	0.90	0.83	0.88	0.34	0.35	0.72	0.01	0.81	0.75	0.58	**0.21**	**AT**
LV	–0.60	–0.82	–0.63	0.57	0.62	0.48	0.59	0.06	0.18	0.38	0.17	0.43	0.31	0.30	**0.20**	**HU**
NL	–0.90	–1.21	–0.57	1.54	0.86	0.79	1.10	0.20	0.36	0.34	0.50	0.76	0.70	0.78	**0.18**	**SK**
NO	–1.66	–1.81	–1.38	0.06	0.81	0.83	0.87	0.55	0.63	0.85	0.00	0.69	0.75	0.57	**0.16**	**RO**
PL	–0.85	–0.90	–0.56	0.31	0.68	0.65	0.73	0.18	0.22	0.33	0.09	0.51	0.52	0.44	**0.16**	**CZ**
PT	–1.38	–1.39	–1.00	0.19	0.91	0.96	0.93	0.42	0.44	0.61	0.05	0.83	0.92	0.63	**0.15**	**LT**
RO	–1.06	–1.14	–0.72	0.39	0.64	0.61	0.81	0.27	0.33	0.44	0.11	0.46	0.47	0.51	**0.12**	**HR**
SE	–1.19	–1.73	–0.82	0.52	0.90	0.84	0.95	0.33	0.59	0.50	0.16	0.81	0.76	0.64	**0.12**	**PL**
SK	–0.68	–1.00	–0.30	0.63	0.87	0.69	0.86	0.10	0.26	0.17	0.19	0.77	0.58	0.56	**0.10**	**TU**
SL	–0.87	–1.06	–0.42	0.47	0.95	0.93	1.04	0.18	0.29	0.25	0.14	0.89	0.89	0.72	**0.09**	**BG**
TU	–0.59	–0.58	–0.82	0.13	0.63	0.64	0.56	0.05	0.07	0.50	0.02	0.44	0.51	0.27	**0.07**	**LV**
UK	–1.22	–1.66	–1.01	2.49	0.85	0.79	1.01	0.34	0.56	0.62	0.83	0.76	0.71	0.70	**0.04**	**EE**
US	–2.65	–2.64	–0.28	2.23	0.93	0.92	1.05	1.00	1.00	0.16	0.74	0.86	0.87	0.73	**0.00**	**CH**

Note: *– using the cumulative data. Columns for FP, GHG and REN elasticity contain several positive values and several statistically insignificant values, e.g. Cyprus REN elasticity = 0.02; but not –0.02. These were not ignored, for it is the value rather than the symbol that is important for indexing. Moreover, the series values subject to this type of indexing must be accompanied by the same symbol. Importance of the symbol is dealt with below. *Source:* Own processing.

In analysis of the Table 4 contents, the attention is primarily drawn by the following facts: intensification of the use of natural resources, GHG emissions and renewable energy use per unit value of GDP being reversely dependent on the growth of environmental taxes per capita. Growth of environmental taxes is naturally accompanied by reduction of environmentally detrimental indicators (FP, GHG). Reduction of REN, being the environmentally friendly indicator, could be explained by behaviour of denominators of the endogenous and exogenous indicators: in the period 1994 – 2015, GDP usually grew faster than the population in the countries of the research sample. Moreover, it could be observed that, in almost half of the analysed countries, usually characterised as sound economies, one percent growth in the tax revenues accounted for the ecological reserve (FP-BC) dividend being higher than one, in about two thirds of the countries – for the drop in GHG emissions, and the forth of the countries – growth in the share of renewable energy.

The U.S. experienced the greatest change (around 3%). It is noteworthy that the cumulative effect, having the narrowing trend when viewed at full scale, partially supports the tendencies discussed above. Weighing of the indexed values has shown that the countries, where the effect of environmental taxes on environmental protection is the highest, are also the countries that are characterised by the greatest ecological deficit: the countries of the European Union, the U.S., and Japan (with certain exceptions). The other end of the list contains the countries that have the smallest or no deficit of natural potential: countries that joined the EU at later stages, also Turkey and the People's Republic of China characterized by large size of population.

The following stage of the study aimed at identifying the specifics of change of *the indicators of environmental state and its maintenance*– GHG emissions, ecological demand (footprint, FP), and renewable energy use (REN) – in individual countries in relation to the environmental tax (ET) revenues, level of economic development (GDP), and energy consumption (EN) by employing the two-step regression approach.

These indicators have been chosen instead of a wider range of indicators for several reasons. *On one hand*, experiments had also been conducted using data for the CO_2 emission and ecological supply (BC) indicators, with the latter not revealing any tendency. Behaviour of the CO_2 indicator had been observed to be identical to that of the GHG indicator in relation to the regressors. Hence, application of the CO_2 indicator in the present research causes overlapping.

On the other hand, the taxes were classified by their purpose. Energy taxes accounted for the largest share of the environmental taxes: in most cases – for about two thirds, and in individual cases – for as many as 90% (e.g., Lithuania, Latvia, Romania, Bulgaria in 2015), less often – for about half of the environmental taxes (e.g., Norway, Netherlands, Denmark, Austria in 2015). This implied the same situation as the one with the CO_2 indicator discussed above.

Third, the attempt to include the population size, number of employed people, population density, labour efficiency, forest area had not brought any significant results. Trend of the endogenous indicators assessed by employing relative values (those with the denominator being the population size or the number of people in employment) was almost the same as in the case of absolute values. The indicator of labour efficiency overlapped with GDP. Equating the forest area with the denominator of the relative indicator had been observed to be insignificant in relation to behaviour of economic indicators.

Hence, the first step („log-log") generated the elasticity of endogenous indicators in relation to exogenous indicators by country, by employing the original time series data and the time series data cumulated year-by-year for the period of 22 years. The case of original data contained several statistically insignificant results, and the respective countries were therefore ignored. Regression tendencies of the time series cumulated year-by-year were statistically significant for all countries.

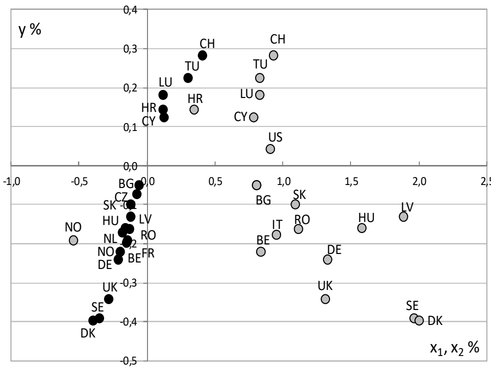
Finally, the second step has involved assessment of the *spatial* distribution of countries by the size of the mentioned effect. In Figures 1.1 and 1.2 variables of the vertical and horizontal axes are elasticity of GHG emissions: in relation to the environmental taxes (y), energy use (x_1), economic capacity, i.e. GDP (x_2).

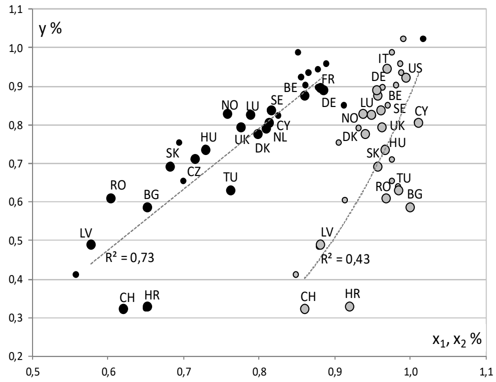
It should be noted that the scatter diagrams presented in the Figure 1 are not intended to depict the regression effect of variables x_1 and x_2 on variable y. They are intended to reveal the specifics (rate, direction, nature) of change of the endogenous indicators. In the Figure 1.2 on the right, larger bubble represents a pair of the elasticity indicators (y&x_1 – grey or y&x_2 – black), corresponding to the country in the Figure 1.1 on the left. The list of countries in the latter is shorter due to presence of insignificant results, as mentioned above.

Graphic visualisation has helped generate insights on certain facts. In Figure 1.1, elasticity of GHG emissions in relation to environmental taxes (hereinafter – GHG_{ET} elasticity) by absolute size varies in the range 0.05 – 0.4% (y). Absolute elasticity percent of GHG_{GDP} has demonstrated similar distribution: 0.05 – 0.5 (x_2). Meanwhile, the rate of change of GHG emissions at one percent growth in energy use (GHG_{EN} elasticity, x_1) in individual cases reached as many as 2% (Sweden, Denmark). Moreover, Quadrants 1, 3, and 4 of the field of coordinates show clear direction and tendency of the rate of change of GHG emissions (Table 5).

F i g u r e 1.1 F i g u r e 1.2

Elasticity of Greenhouse Gas Emissions Associated with Change in Environmental Tax Revenues (*y*), Energy Use (x_1), and GDP (x_2)





Note: Using the original data of GHG, ET, EN and GDP.

Note: Using the cumulative data of GHG, ET, EN and GDP.

Source: Own processing.

In countries of Quadrant 4, GHG_{EN} elasticity is greater than GHG_{GDP} and GHG_{ET} elasticity. This indicates that higher energy use caused higher GHG emissions compared to economic development or environmental taxes that did not have any opposite (environmentally friendly) effect on the emissions. In countries of Quadrant 4, higher energy use also led to greater increase of GHG emissions compared to environmental taxes, where the latter had opposite effect on the emissions: the emissions tended to reduce slower in the countries that joined the EU at later stages (Romania, Hungary, Latvia, Slovakia, Bulgaria), and faster in economically more sound old EU member countries (Denmark, Sweden, the United Kingdom, Germany, Belgium, Italy). The countries as referred to above (plus the Czech Republic, Norway, and the Netherlands) rank under the similar pattern in Quadrant 3.

The scatter diagram of cumulated time series has other advantages compared to the previous case. It could be observed that all the indicators vary in the range from 0 to approximately 1. The cumulation could be equated to indexation, which allows harmonise scales of the indicators that are subject to comparison. Here, countries of Quadrant 3 in Figure 1.1 have scattered under the similar pattern above the left trend line (irrespective of minor deviation), while countries of Quadrant 1 are situated below. Countries of Quadrant 2 have scattered above the right trend line (with minor deviation), while those of Quadrant 1 – below the right trend line. Moreover, it can be clearly observed that energy effect on the environment is considerably stronger than economic and tax effect, although tax effect on the environment is usually stronger than economic effect. With certain exceptions (China, Croatia, Latvia) ignored, the link between rates of change of GHG_{ET} vs. GHG_{EN} is non-linear in contrast to the obviously linear GHG_{ET} vs. GHG_{GDP} link.

T a b l e 5

Tendency of Elasticity of Greenhouse Gas Emissions

Elasticity	**i.e. changing tend of**	**due to 1% growth of the**	**Quadrant 1**		**Quadrant 3**		**Quadrant 4**	
			tendency	countries	tendency	countries	properties	tendency
y	GHG	ET	rising	CH, TU, LU*, HR*, CY, US	decreasing	DK*, SE*, UK*, DE*, BE*, NO*, FR*, NL, RO*, HU, LV*, SK, CZ, BG	decreasing	DK, SE, UK, DE, BE, IT, RO, HU, LV, SK, BG
x_1	GHG	EN	rising (grey)	as well as the *y*'s case	decreasing (grey)	NO (as outlier)	rising (grey)	as well as the *y*'s case
x_2	GHG	GDP	rising (black)	CH, TU, LU, HR, CY	decreasing (black)	as well as the *y*'s case		

Note: * Countries where tax effect on the environment is stronger than the economic effect (GDP) are tagged with an asterisk.

Source: Own processing.

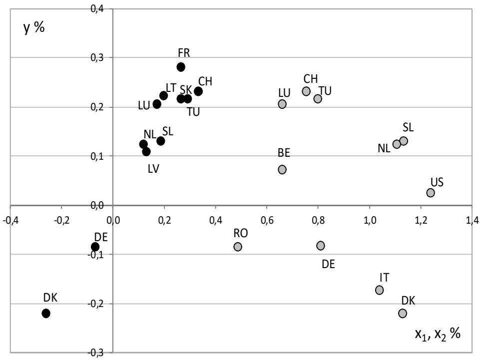
Analysis of the issue gains more substance, when all the factors are considered. Ecological footprint (FP), or ecological demand, reflecting the scope of consumption of natural resources, has been introduced further as another „environmentally friendly" indicator.

Scatter diagrams 2.1 and 2.2 scatter could be claimed to be very similar to the diagrams of the case dealt with above. They are similar in relation to the endogenous indicators, FP elasticity, ET tendencies, energy use, and economic development.

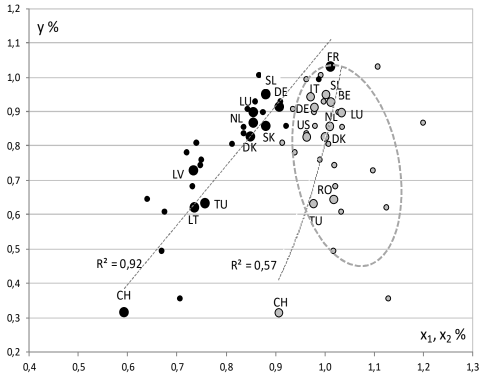
The only difference is that only 2 countries (Denmark and Germany) have remained in Quadrant 3 – the most „environmentally-friendly" one, 4 – in Quadrant 4, while five more countries have entered the least „friendly" Quadrant 1. Countries characterised by statistically insignificant results have been ignored. Elasticity of ecological supply in relation to environmental taxes – FP_{ET} – ranges from 0.02 to 0.23% (*y*), while FP_{GDP} elasticity – from 0.07 – 0.33% (x_1), rate of change of FP_{EN} – from 0.5 to 1.25% (x_2) by absolute size. It is noteworthy that, compared to the previous case, the range of rate of change of ecological supply is narrower in case of one percent growth of taxes, energy use, and economy. This statistics generated by the authors has suggested the conclusion that the rate of change of „use" is slower compared to the rate of change of GHG emissions in view of the fiscal, energy, and economic factors.

F i g u r e 2.1 F i g u r e 2.2

Elasticity of Footprint Associated with Change in Environmental Tax Revenues (*y*), Energy Use (x_1) and GDP (x_2)



Note: Using the original data of FP, ET, EN and GDP.



Note: Using the cumulative data of FP, ET, EN and GDP.

Source: Own processing.

Analysis of Figure 2 on the left and on the right supports the aspect revealed previously, namely, that higher energy use has greater effect on the indicator of environmental friendliness than economic development or fiscal instruments. Stronger economies characterised by greater environmental effect of environmental taxes and are settled on the top of the right diagram, while the Baltic countries and Turkey (by economic effect on environment) and Romania and Turkey, with their geographical proximity (by energy effect on environment) are on the lower level. Same as in the previous case, the People's Republic of China is on the lowest level. Compared to other countries of the research sample, China's GDP saw the most rapid growth in the period analysed (15.5% on average annually), energy use (5.6% annually) and environmental taxes (17.7% annually). Moreover, it follows Slovakia by natural resource use in global hectares (3.9% annually). In addition, ecological demand grew in Lithuania by 3.8% on average annually (placed 3rd), followed by Croatia and Latvia.

Tendencies of change of the ecological footprint by countries are presented in details in Table 6.

In general, it could be claimed that fiscal effect on the environment is stronger than economic effect in countries of Quadrant 1 only (France, Lithuania, Luxembourg, Netherlands), with this quadrant being the least „environmentally-friendly". The study progresses further by employing renewable energy use (REN) in relation to environmental taxes (ET), total energy consumption (EN) in countries of the research sample and their economic development (GDP) as the criterion of maintenance of natural energy resources.

T a b l e 6

Tendency of Footprint Elasticity of Analysed Countries

Elasticity	**i.e. changing tend of**	**due to 1% growth of the**	**Quadrant 1**		**Quadrant 3**		**Quadrant 4**	
			tendency	countries	tendency	countries	properties	tendency
y	FP	ET	rising	FR*, CH, LT*, TU, SK, LU*, SL, NL*, LV, BE, US	decreasing	DK, DE*	decreasing	DK, IT, DE, RO
x_1	FP	EN	rising (grey)	US, SL, NL,TU, CH, LU, BE	decreasing (grey)		rising (grey)	as well as the *y*'s case
x_2	FP	GDP	rising (black)	CH, TU, SK, FR, LT, SL, LU, LV, NL	decreasing (black)	as well as the *y*'s case		

Note: * Countries where tax effect on the environment is stronger than the economic effect (GDP) are tagged with an asterisk.

Source: Own processing.

Scatter diagram 3.1 suggests that there are considerably more countries, where REN elasticity in relation to environmental taxes increases along with its increasing elasticity in relation to GDP (Quadrant 1). Three times smaller effect in terms of energy is characteristic of 7 countries only. Moreover, 7 countries have demonstrated the reverse tendency: the greater is the negative energy effect, the greater is the positive fiscal effect (Quadrant 2).

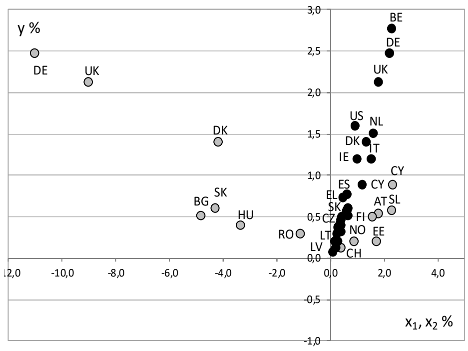
It can be clearly noticed that REN elasticity in relation to all the three denominators (ET, GDP, EN) is considerably greater than in the previous case. The rate of change of REN_{ET} ranges from 0.1 to 2.8% (y), REN_{GDP} – from 0.1 to 2.3% (x_1), FP_{EN} – from 0.4 to 11% (x_2).

Scale of the right diagram also extends well beyond 1. This supports that growth in demand for renewable energy is considerably faster compared to the rate of change of GHG emissions and natural resource use at one percent growth of environmental taxes, total energy consumption, and GDP.

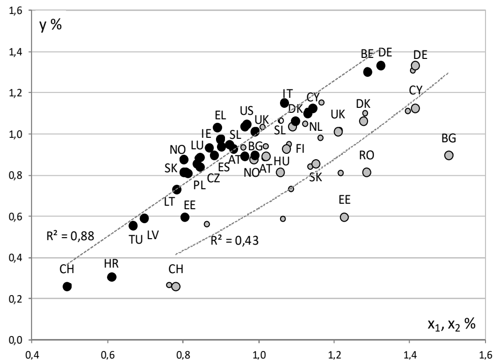
The leading countries in the right diagram are again the stronger economies and, additionally, Cyprus, where ET effect on the environment is quite greater. Stronger energy effect on growth of the demand for renewable resources is characteristic of Germany, the United Kingdom, and Denmark; smaller – in geographically proximate countries: Slovakia, Bulgaria, Hungary, and Romania (Figure 3 on the left). Smaller economic effect is, again, characteristic to the Baltic countries, the Czech Republic, Slovakia, Poland, and Turkey (Figure on the right). The mentioned effects could be claimed to be insignificant in China and Croatia. The countries with attributes „smaller effect" and „the smallest effect" are scattered below the both trend lines in Figure 3. According to achieved results, the rate of growth of environmental taxes and GDP in these countries in the period analysed is considerably greater than the rate of growth of energy use (under the uniform scale) compared to other countries of the analysed sample. For example, in Lithuania, the respective comparison values are 45 and 43%, Latvia – 78 and 46%, Estonia – 113 and 44%, Poland – 49 and 38%, while in Germany – 8 and 10%.

F i g u r e 3.1 F i g u r e 3.2

Elasticity of Renewable Energy Use Associated with Change in Environmental Tax Revenues (y), Energy use (x_1), and GDP (x_2)



Note: Using the original data of REN, ET, EN and GDP.



Note: Using the cumulative data of REN, ET, EN and GDP.

Source: Own processing.

Tendencies in the growth of renewable energy use are presented by countries in details in Table 7.

T a b l e 7

Tendency of Elasticity of Renewable Energy Use

Elasticity	i.e. changing tend of	due to 1% growth of the	Quadrant 1		Quadrant 2	
			tendency	countries	tendency	countries
y	REN	ET	rising	Most of the countries*, except IT, NL, CY, SK, CZ, SL, AT, BG, PL, EE, LV, CH	rising	DE, UK, DK, SK, BG, HU, RO
x_1	REN	EN	rising (grey)	CY, SL, AT, FI, EE, NO, CH	decreasing (grey)	as well as the y's case
x_2	REN	GDP	rising (black)	as well as the y's case		

Note: * Countries where tax effect on the environment is stronger than the economic effect – $y > x_2$ – are tagged with an asterisk.

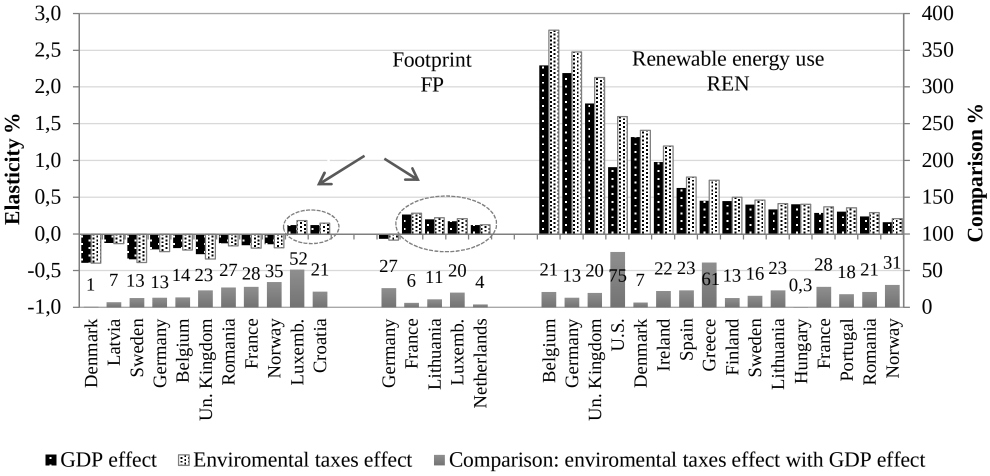
Source: Author's calculations.

It should be noted that REN_{ET} elasticity exceeds the rate of change of REN_{GDP} ($y > x_2$) in almost all countries of the research sample, except for twelve countries (see „Most"*). In fact, Croatia, Japan, Luxembourg, and Turkey are not listed as „Most" in Quadrant 1 due to statistical insignificance of ET and GDP effects.

It should be emphasized that conducted study has provided more possibilities for more correct assessment of the environmental tax *effect* on environmentally *favourable trends representing indicators:* GHG emissions, use of natural resources (FP), and renewable energy use (REN). The study has revealed that fiscal effect is similar to the economic effect and absolutely lags behind energy effect. Energy effect simply pushes the fiscal effect far into the background. The Figure 4 below depicts distribution of stronger tax effect by size, and countries are compared in terms of the GDP growth effect on the environment. The effect in ellipse means positive GHG and FP gain per 1% ET and GDP growth. Although insignificant, the gain still shows environmental unfriendliness.

Figure 4

Effect of Environmental Tax Revenues and GDP on Environment



Source: Own processing.

ET effect on GHG emissions could be considered to be more prominent in Denmark, Sweden, the United Kingdom, Germany, and Belgium, and less prominent in Norway, France, Romania, and Latvia. Insignificant fiscal effect on the natural resource use in global hectares is characteristic of Germany only. Tax policy with strong focus on promotion of renewable energy generation and implementation of new technologies provides far greater effect compared to elasticity of the indicators of GHG emissions and natural resource use in relation to all environmental taxes. As mentioned above, energy taxes account for the major share of environmental taxes. For example in 2015 revenues from energy taxes in Germany, Spain, Sweden, Lithuania, France, Romania accounted for 80 – 90% of the total environmental tax revenues; in Belgium, the United Kingdom, the U.S., Greece, Finland, Hungary – about 60 – 75%; Denmark, Ireland, Norway – up to 60% (where $REN_{ET\_EFFECT} > REN_{GDP\_EFFECT}$).

Further analysis depicted from Figure 4 focuses on the observation that countries of the large GHG emission section moved to the more abundant REN section (plus the U.S., Ireland, Spain, Greece, Finland, Hungary, Portugal, and Lithuania that has replaced Latvia). In the period 1994 – 2015, the rate of average annual growth of environmental tax revenues and GDP in these countries was similar: in Germany and Greece – 2%, Lithuania and Romania – 8 – 10%, Ireland – 6 and 8%, other countries – 3 – 5%. The most rapid growth of renewable energy use was registered in Belgium, the United Kingdom, Germany, Ireland (9 – 12% annually), the slowest – in France and Norway (1%). Germany stood out in this sample of countries in most cases, as its tax and GDP growth were relatively small compared to renewable energy use. Moreover, the share of renewable energy in the total energy consumption was the largest in the Scandinavian and Baltic countries analysed, plus Portugal: Norway (56%, 2015 m.), Sweden (50%), Finland (42%), Latvia (41%), Denmark (33%), Portugal (31%), and Lithuania (30%). For example, the share of renewables in total energy consumption was only 15% in Germany. In general, it can be noticed that environmental tax effect is stronger in economically more sound countries, where the economic and tax growth rates are quite slow and sustainable and renewable energy production technologies are being developed at higher rates.

Conclusion

The general trend for the European Union and other analysed countries of the sample show reduction in the greenhouse gas emissions, increase in renewable energy use and revenues from environmental taxes, economic growth, and reduction in energy consumption growth rates.

The study has demonstrated that with increase of revenues from environmental taxes in analysed countries, the environmentally unfriendly indicators tend to reduce. The leading countries in terms of *environmental protection* have been found to be the countries with the largest ecological deficit: countries of the European Union, the U.S., and Japan, while the outsider countries in this field are the countries with the smallest or absent deficit, usually these are the countries that joined the EU at later stages.

The research has revealed that the effect of environmental taxes is very close to the economic effect, and lags behind the energy effect on environmental protection. The energy consumption effect is considerably stronger. In addition, the environmental tax effect on environmental protection is stronger in economically more sound countries with slower economic and tax growth rates and more rapid development of renewable energy production technologies.

The role of environmental taxes is more prominent where the level of energy resource consumption is maintained at the expense of renewable energy use, with the CO_2 emissions not rising as the result of increased use of renewables.

Ecological taxation encourages development and implementation of new technologies that mitigate pollution and, at the same time has positive impact on creation of new jobs.

Therefore ecological tax reform, i.e. shifting tax burden from labour taxes to environmental taxes may provide for double dividends: increase of environmental quality and economic growth and increase of employment.

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