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Environmental Policy Instruments and Greenhouse Gas Emissions: VAR Analysis

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Abstract**—**The paper examines the interaction between the environmental taxation, size of government spending on environmental protection and greenhouse gas emissions and gross inland energy consumption. The aim is to analyze the effects of environmental taxation and government spending on environmental protection as an environmental policy instruments on greenhouse gas emissions and gross inland energy consumption in the EU15. The empirical study is performed using a VAR approach with the application of aggregated data of EU15 over the period 1995 to 2012. The results provide the evidence that the reactions of greenhouse gas emission and gross inland energy consumption to the shocks of environmental policy instruments are strong, mainly in the short term and decay to zero after about 8 years. Further, the reactions of the environmental policy instruments to the shocks of greenhouse gas emission and gross inland energy consumption are also strong in the short term, however with the deferred effects. In addition, the results show that government spending on environmental protection together with gross inland energy consumption has stronger effect on greenhouse gas emissions than environmental taxes in EU15 over the examined period.

Keywords**—**VAR analysis, greenhouse gas emissions, environmental taxation, government spending.

I. INTRODUCTION

NOWADAYS, the effect of environmental taxation on declining of the greenhouse gas emission has been more often discussed, mainly due to the facts that the European Commission proposed revision of the Directive 2003/96/EC on taxation of energy products and electricity. This directive introduces CO_2-related taxation, for EU committed to reduce its greenhouse gas emissions at 40% in 2030 compared to 1990 levels. However, it is a question whether new carbon taxation can be a suitable tool for the reduction of greenhouse gas emissions or just an instrument for increasing state budget revenues after the economic crisis. Moreover, it can also be discussed, whether environmental taxation together with government spending on environmental protection creates a suitable combination of tools for achieving the reduction of greenhouse gas emission.

The aim of the paper is to analyze the effects of environmental taxation and government spending on environmental protection as an environmental policy instruments on greenhouse gas emissions and gross inland energy consumption in the EU15. The empirical study employs VAR approach using aggregated data of EU15 over the period 1995 to 2012. Based on the results, more accurate environmental policy decisions can be formulated to achieve a decline of greenhouse gas emission.

II. LITERATURE REVIEW

There can be identified four basic types of environmental policy instruments in the literature [1] - charges and taxes, tradable emissions permits, subsidies, and deposit-refund systems. Currently in the EU, the most commonly used environmental policy instruments represent taxes and EU Emissions Trading Systems.

The first one, environmental taxes, are usually levied to discourage behavior that is potentially harmful to the environment [2]. The rationale for environmental taxes was developed by economist Arthur Pigou and is based on the existence of environmental externalities, which are not covered in the valuation of products. Hence, the levy a tax on the activities giving rise to the externalities, i.e. which are harmful to the environment or which cause CO_2 emissions, is a solution for properly valuation of product [3]. Further, the preservation of the environment and control of externalities is considered as one of the goals of selective taxes [4]. Currently, on the level of EU the Directive 2003/96/EC on taxation of energy products and electricity is effective, however, it does not reflect the energy content or the CO_2 emissions of the taxed energy products. Due to this fact, the European Commission proposed its revision on 13 April 2011 introducing CO_2-related taxation in the amount of EUR 20 per tonne of CO_2.

The second one, the EU Emissions Trading System (hereinafter EU ETS), which was established in 2005, works on the cap-trade principle and covers major energy and industrial installations (small installations and other sectors are excluded EU ETS system). During the I. and II. phases of its trading phases, the emissions allowances were distributed for free by governments, subsequently, during III. phase, the emissions allowances have been auctioned. However, after economic crises a large surplus of allowances was generated with result of significant decline in the carbon price. On June 2014, the weighted average clearing price was EUR 5.53 per emissions allowances [5]. As a result, EU ETS does not create a desirable result in the form of consistent CO_2 price signal for strategic environmental investment decisions [6].

With respect to the climate change, environmental taxes and tradable emissions permits are considered as cost-effective instruments to influence consumers and producers behavior

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[7]. Application of environmental taxes and tradable emissions permits motivates consumers and producers to use natural resources responsively and to limit or avoid environmental pollution [8]. In addition, environmental taxes generate revenue that can be used for environmental protection as a government spending.

The scope of the government spending on environmental protection is defined according to the Classification of Environmental Protection Activities CEPA 2000, which distinguishes nine environmental domains: protection of ambient air and climate; wastewater management; waste management; protection and remediation of soil, groundwater and surface water; noise and vibration abatement; protection of biodiversity and landscape; protection against radiation; research and development; and other environmental protection activities. In 2011, the average amount of government spending in EU27 was EUR 166 per capita [9].

As regards the government spending on environmental protection, it is not recommended to compensate those sectors of economy that are affected by the environmental tax. There is risk not achieving the environmental goal with continuing to increase emissions [10]. The compensation is only desirable for the poorer segments of the population with aim to reduce the regressivity of the tax [11].

III. MATERIAL AND METHODS

The effects of environmental taxation and government spending on environmental protection as an environmental policy instruments on greenhouse gas emissions in the EU15 are examined by employing Vector Autoregressive models (VAR).

VAR model is used as a technique for describing the dynamic behavior of economic and financial time series, and is a prevalent method of time-series modeling and forecasting [12]-[14]. Furthermore, the VAR model is also used for structural inference and policy analysis, therefore the VAR models are now well established in applied macroeconomics. The technical reference for VAR models are mainly in Lütkepohl, Watson, Waggoner and Zha, and others [15]-[18].

In VAR models all variables are treated as endogenous and interdependent, both in a dynamic and in a static sense, although in some relevant cases, exogenous variables could be included [19]. We introduce 4 endogenous variables in our VAR models - greenhouse gas emissions (hereinafter GHE), gross inland energy consumption (hereinafter GIC, which represents the quantity of energy consumed within the borders of a country, including energy consumed in the form of electricity, heating and transport.), environmental tax revenues (hereinafter TET) and government spending on environmental protection (hereinafter GE). The model can be specified as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + \in_t \qquad (1)$$

where yt (n x 1) represents a vector of four endogenous variables, Ai (n x n) are coefficient matrices. The number of lags p is called the order of the VAR. Subscripts t refers to time. The vector $\in t$ is a vector of white noise, with covariance matrix $\sum$.

TABLE I
DESCRIPTION STATISTICS AND CORRELATION MATRIX FOR VARIABLES

Variab.	Mean	Std. Dev	Min	Max	GE	TET	GHE	GIC
GE	0.77	4.39	-4.39	11.13	1			
TET	2.70	2.61	-3.17	7.47	-0.34	1		
GHE	-0.55	2.19	-7.11	2.18	-0.26	0.43	1	
GIC	100.0	23.72	0.00	103.8	0.07	0.27	0.00	1

(Source: Gretl, own processing)

All variables are presented as an annual continuously-compounded growth rate. Further, GHE is converted to a per capita basis by dividing through the population number. As a data source served the Eurostat databases and cover the period from 1995 to 2012 with yearly frequency. Their descriptive statistics and correlation matrix are shown in Table I. As can be seen, the negative correlation was identified only in government spending on environmental protection to environmental tax revenues and greenhouse gas emissions. Growth rates fluctuate within a relatively broad band between 1995 and 2012.

Before employing VAR analysis, it is essential to verify that all variables in VAR model are integrated of order one in levels, i.e. that series are stationary. For that purpose the Augmented Dickey-Fuller test and KPSS test for stationarity were used. In case of the Augmented Dickey-Fuller test (hereinafter ADF test), two tests were applied - specifically the test with individual intercept and test with individual intercept and trend, where the null hypothesis being that the variable has a unit root. Furthermore, in case of the ADF test, another variant was used, namely the Augmented Dickey–Fuller test with GLS procedure suggested by Elliott, Rothenberg and Stock [20]. This gives a higher significance than the standard ADF test. In case of the KPSS test, the null hypothesis is that variables are stationary around a level. The critical values of KPSS test are based on the response surfaces estimated by Sephton [21], which are more accurate for small samples. Based on the results of unit root tests, the first differences of variables were added, specifically in case of GE as d_GE and in case of TET as d_TET.

Subsequently, the optimal VAR lag-length selection was determined using model selection criteria. There can be identified the three most common information criteria, specifically the Akaike (AIC), Schwartz (BIC) and Hannan-Quinn (HQC). The general approach is to choose the value of lag which minimizes some model selection criteria. Based on the results, a lag of length one was selected as the optimal.

When the unit root tests are performed and all variables are stationary, the VAR model is employed. Moreover, for each variable in VAR model the F test is computed in the form of Granger causality test, in which the null hypothesis is that no lags of variable are significant in the equation for variable. According to the Granger causality test, it is possible to determine if the growth rate of variables affect one another over time. Based on the results presented in Table II, it can be concluded that the null hypothesis cannot be rejected.

TABLE II
RESULTS OF GRANGER CAUSALITY TEST IN VAR MODEL

Variables	GHE_{t-1}	GIC_{t-1}	d_TET_{t-1}	d_GE_{t-1}
GHE_t	1.143 (0.307)	0.881 (0.367)	2.575 (0.136)	0.948 (0.350)
GIC_t	1.474 (0.250)	1.271 (0.283)	2.342 (0.154)	1.307 (0.277)
d_TET_t	1.079 (0.321)	0.479 (0.503)	0.001 (0.973)	5.765 (0.035)
d_GE_t	5.558 (0.038)	6.053 (0.031)	1.224 (0.292)	5.687 (0.036)

(Source: Gretl, own processing)

Once all the coefficients of the VAR model and optimal VAR lag-length are estimated, the impulse response functions (hereinafter IRF) and the forecast error variance decompositions (hereinafter FEVDC) were computed. The IRF describes the response of a variable over time to a shock in another variable in the system i.e. what the additive effect is to current and future variable if the shock in another variable is added in. The FEVDC measure contributes of each source of shock to the forecast error variance of each variable, at a given 10 forecast horizons. The FEVDC and IFR are based on the Cholesky decomposition of the contemporaneous covariance matrix, and in this context the order in which the variables are given matters. There is an assumption that the first variable in the list is "most exogenous" within period. Moreover, the variables listed earlier in the VAR order impact the other variables contemporaneously, while variables listed later in the VAR order impact those listed earlier only with lag. In our case the order was GHE, GIC, d_TET and d_GE. Further, the 90% confidence interval for the responses using the bootstrap method was used, when the residuals from the VAR model were resampled with 999 replications.

IV. RESULTS AND DISCUSSION

To estimate impulse response functions and to describe the effect of environmental policy instruments on greenhouse gas emission VAR techniques are used in the paper. Table III shows the results of unit root tests which are essential before employing VAR analysis. The tests show that some of the variables, namely GE and TET are not stationary in levels, thus their first differences were added and tested (d_GE and d_TET). Subsequently, based on the Augmented Dickey-Fuller tests (basic and with GLS procedure) in the form of individual intercept, it can be considered that GHE and GIC variables are stationary in levels and d_GE and d_TET are stationary in first-difference.

When the variables are stacionary, the VAR model can be performed. Table IV shows the results of the estimation of coefficients and standard deviations for each of variable. Based on the results, we can conclude that there is a positive and statistically significant relationship between gross inland energy consumption together with greenhouse gas emissions and government spending on environmental protection at the 5% level of significance. Further, there is a negative and statistically significant relationship between government spending on environmental protection and environmental tax revenues at 5% level of the significance.

TABLE III
UNIT ROOT TESTS

Variables	KPSS	Augmented Dickey-Fuller		ADF with GLS	
		Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend
GE	0.196 (n.a.)	-3.021 (0.052)	-3.000 (0.160)	-3,088 (0.001)	-3,218 (n.a.)
d_GE	0.0724 (n.a.)	**-5.957** **(0.000)**	-5.835 (0.001)	**-6.147** **(2.095e-009)**	-6.208 (n.a.)
TET	0.271 (n.a.)	-2.648 (0.103)	-3.336 (0.093)	-2,624 (0.008)	-3,300 (n.a.)
d_TET	0.086 (n.a.)	**-4.080** **(0.001)**	-4.469 (0.014)	**-4.074** **(4.751e-005)**	-4.457 (n.a.)
GHE	0.402 (0.083)	**-4.829** **(0.001)**	-6.442 (0.000)	**-4,954** **(9,311e-007)**	-6,794 (n.a.)
GIC	0.290 (n.a.)	**-44.173** **(0.000)**	-42.412 (1)	**-3,742** **(0,000)**	-6,287 (n.a.)

(Source: Gretl, own processing)

TABLE IV
ESTIMATION OF COEFFICIENTS AND STANDARD DEVIATIONS IN VAR MODEL

Variables	GHE_t	GIC_t	d_TET_t	d_GE_t
constant	98.631 (82.050)	194.888 (84.33)**	-154.253 (100.399)	-277.549 (243.57)
GHE_{t-1}	0.938 (0.877)	0.850 (0.906)	-1.828 (1.139)	-2.33 (2.398)
GIC_{t-1}	-0.986 (0.812)	-0.940 (0.834)	1.523 (0.995)	2.754 (2.409)
d_TET_{t-1}	0.193 (0.186)	0.127 (0.184)	-0.005 (0.158)	-0.763 (0.318)**
d_GE_{t-1}	0.241 (0.102)**	0.245 (0.099)**	0.118 (0.106)	-0.450 (0.188)**

Note: ** indicate significance at the 5% level.
(Source: Gretl, own processing)

Fig. 1 shows the impulse responses. The grey lines indicate 90% confidence interval around the estimation. The vertical axis represents the percentile magnitude of one-standard deviation shock to a related variable. The horizontal axis represents time elapsed in annual basis after the impulse is given, totally 10 years. The responses of GHE growth rate to unexpected shocks in the amount of one-standard deviation to the other variables are given in the first row of Fig. 1. Most notable is the strong negative response of GHE to an unexpected decrease in GIC growth rate. It takes about 6 years for the effect of the shock to dissipate. Furthermore, it was identified the zero responses of GHE in the first period to an unexpected increase in TET growth rate (around 2 percentage points). However, the strong negative response of GHE on this shock was reached after the second period, where the minimum level (around -0.15 percentage points) was gained. It is visible that this shock has the deferred effect which decays to zero after about 4 years. Moreover, the response of GHE growth rate to an unexpected shock in GE growth rate shows that if the GE growth rate decreases (increases) the GHE growth rate increases (decreases) without deferred effect.

The responses of GIC growth rate to the shocks are shown in the second row of Fig. 1. Most notable is the strong negative response of GIC growth rate to an unexpected increase in TET growth rate (around 2 percentage points). There was also identified the deferred effect of the shock, which reached its minimal level (around -0.16 percentage points) after 3 years. Furthermore, the responses of GIC growth rate on the shocks in GE growth rate are fluctuating. The positive (negative) response of GIC was identified to an unexpected decrease (increase) in GE. Moreover, the response of GIC growth rate on the shocks in GHE growth rate is dependent on the actions of GHE.

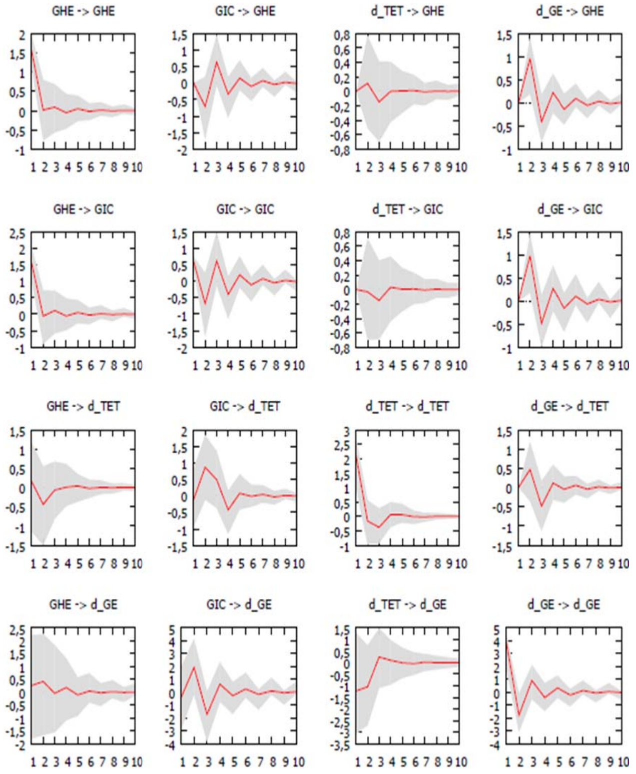

Fig. 1 Impulse-responses for 1 lag VAR of GHE, GIC, d_TET, d_GE (Source: Gretl, own processing)

The responses of TET growth rate to the shocks are given in the third row of Fig 1. Most notable is the strong positive response of TET growth rate to an unexpected increase (shock) in GHE growth rate (around 1.6 percentage points), which has deferred effect. The TET growth rate was increasing during 3 years. The effect of the shock decays to zero after 8 years. Further, there is visible deferred effect of the shocks in GIC growth rate on the TET growth rate, i.e. the GIC growth rate is increased (decreased), the TET growth rate is increased (decreased) about one years after that. Furthermore, the responses of TET growth rate to the shock in GE growth rate proved the assumption that increased GE are usually covered by TET, i.e. when the GE growth rate is increased, the TET growth rate is also increased but with one year delay.

The responses of GE growth rate to the shocks are given in the last row of Fig. 1. Most notable is the strong positive response of GE growth rate (around 0.3 percentage points in the first year and up to 0.4 percentage points in the second year) to an unexpected increase in GHE growth rate. The shock decays to zero after about 9 years. Further, the response of GE growth rate to the shock in TET growth rate (around 2 percentage points) is strongly negative (around -1.2 percentage points). However, there is visible the deferred effect of the shock on the GE growth rate. The last response of GE growth rare to the shock in GIC growth rate (around 0.6 percentage points) is positive, however with the deferred effect of one year.

The last part of VAR analysis is the forecast error variance, which shows the contributions of each source of shock to the forecast error variance of each variable. The results of FEVDC analysis confirm the results of impulse responses, i.e. the deferred effect of some shocks (see Table V). Further, the unexpected shock in GHE is explained by around 24-25% of GE, around 13-22% of GIC and 0.3-0.7% of TET, where are also deferred effects on those variables. The unexpected shock in GIC is explained by around 46-86% of GHE, around 13-27% of GE, and around 0.4 -0.5% of TET (on the last two variables are deferred effects). The unexpected shock in TET is explained by around 0.5-3.8% of GHE, around 0.2-18% of GIC, around 3-7% of GE (on the last variable is deferred effect). The unexpected shock in GE is explained by around 0.9-24% of GIC, around 8-10% of TET and around 0.3-0.9% of GHE. For details see Table V.

TABLE V
FORECAST ERROR VARIANCE DECOMPOSITIONS

Variables	Period*	Std. Dev	GHE	GIC	d_TET	d_GE
GHE	1	1.533	100	**0.00**	**0.00**	**0.00**
	2	1.953	62.130	13.294	0.317	24.256
	3	2.099	53.922	20.580	0.763	24.733
	4	2.138	52.039	22.314	0.736	24.909
	8	2.156	51.256	22.809	0.729	25.204
	10	2.156	51.242	22.819	0.729	25.208
GIC	1	1.653	86.892	13.107	**0.00**	**0.00**
	2	2.039	57.203	19.700	0.027	23.069
	3	2.193	49.742	24.913	0.506	24.837
	4	2.247	47.436	26.959	0.500	25.104
	8	2.269	46.563	27.549	0.493	25.394
	10	2.270	46.548	27.559	0.493	25.399
d_TET	1	2.106	0.534	0.282	99.183	**0.00**
	2	2.370	3.809	13.501	78.751	3.937
	3	2.497	3.499	16.012	73.232	7.255
	4	2.536	3.392	18.339	71.035	7.231
	8	2.541	3.414	18.416	70.850	7.317
	10	2.541	3.414	18.419	70.846	7.319
d_GE	1	4.199	0.384	0.965	8.538	90.111
	2	5.081	0.928	14.946	10.094	74.030
	3	5.448	0.815	23.095	8.975	67.114
	4	5.504	0.906	23.910	8.827	66.355
	8	5.538	0.941	24.197	8.729	66.131
	10	5.538	0.942	24.204	8.727	66.126

*Duplicated values were omitted.
(Source: Gretl, own processing)

V. CONCLUSION

The aim of the article was to examine the effect of environmental taxation and government spending on environmental protection as an environmental policy instruments on greenhouse gas emissions and gross inland energy consumption in the EU15 by using a VAR approach on the aggregated data of EU15 over the period 1995 to 2012.

The results show that reactions of greenhouse gas emission and gross inland energy consumption to the shocks of environmental taxes and government spending on environmental protection are strong, mainly in the short term. However, these shocks usually decay to zero after about 8 years. The reactions of the environmental policy instruments to the shocks of GHE and GIC are also strong in the short term, however with the deferred effects. Further, it was indicated that only GE from the environmental policy instruments together with GIC are the main contributors to the shock in GHE, specifically around 24% in case of GE and 20% in case of GIC. The environmental taxes contribute on the shock in GHE at minimal level around 1%. In the respect of GIC was also indicated that GHE (around 46-86%) and GE (around 24%) are the main contributors to the shock in GIC. In case of the shocks in environmental policy instruments, firstly in GE, the main contributors are GIC (around 23%) and TET (around 8%), minimal effect around 1% has GHE. Secondly, in TET the main contributors are GIC (around 18%) and GE (around 7%), GHE contributes only around 3%.

Based on the results, it can be concluded that government spending on environmental protection together with gross inland energy consumption has stronger effect on greenhouse gas emissions than environmental taxes in EU15.

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