sustainability

MDPI

Article

Efficiency of Energy Taxes and the Validity of the Residential Electricity Environmental Kuznets Curve in the European Union

Djula Borozan

Faculty of Economics in Osijek, Josip Juraj Strossmayer University of Osijek, Gajev trg 7, HR 31000 Osijek, Croatia; borozan@efos.hr

Received: 5 June 2018; Accepted: 10 July 2018; Published: 13 July 2018

Abstract: To achieve the energy targets, energy policy of the European Union (EU) is trying to discourage residential electricity consumption employing different measures but without worsening the quality of life and jeopardizing its economic growth and development at the same time. This paper aims to directly and indirectly explore the effects of energy taxes on household electricity consumption and test the validity of the household electricity environmental Kuznets curve (EEKC) in a multivariate setting and a system generalized method of moments framework for EU member countries in the period 2005–2016. The results reveal that energy taxes influence electricity consumption more efficiently through energy prices than directly and in the long-run. Efficiency of energy taxes can be reinforced by combining changes in energy prices and policy measures that change the electricity consumption behavior patterns. As for the EEKC, the paper corroborates its inverted U-shaped form, assuming thereby at least the same level of policy efforts directed to accomplish the energy targets and household willingness to use goods in an environmentally friendly way.

Keywords: energy taxes; electricity consumption; environmental Kuznets curve; human capital; dynamic panel analysis

1. Introduction

The European Union (EU) wants to become a competitive, low-carbon and energy efficient economy [1–3]. To that end, an increase in energy efficiency and a reduction in greenhouse gas (GHG) emissions are very important. According to the 2030 Energy Strategy [3], energy targets for 2030 include a cut in GHG emissions by 40% (from 1990 levels), energy saving of at least 27% and energy efficiency improvement by 30% compared with a business-as-usual scenario.

According to the Eurostat database on energy [4], households account for approximately 30% of final electricity consumption and 25% of final energy consumption in the EU. After natural gas, electricity is the most-consumed energy source in the residential sector. Hence, it plays an important role in reaching the EU energy targets. An important step to achieve them is to decrease residential electricity consumption without worsening the quality of life and jeopardizing economic growth and development. A decrease in electricity consumption may be a consequence of an electricity efficiency improvement or a reduction in the amount of service used. The former is desirable from the energy efficiency target point of view, but the latter may be a sign of deterioration in the quality of life. Although an improvement in electricity efficiency does not necessarily lead to energy saving or adverse GHG emission reduction, it is assumed in this paper that reducing residential electricity consumption is beneficial and desirable until it results in deteriorating the quality of life. The EU has used several energy policy instruments and adopted a number of measures to influence the behavior of economic agents including households, improve energy efficiency in general, reduce energy consumption and consequently reduce GHG emissions. Such measures include, for example, energy price increases through the introduction of ecological taxes, tradable or non-tradable emission permits; green, white or brown certificates; subsidies; and mandatory energy-saving measures in the construction and renovation of buildings [5].

In this paper, we focus on energy taxes which are taxes on energy products such as fuel, transport and electricity. According to the Eurostat database on energy [4], on average, energy tax revenues have accounted for slightly less than 2% of gross domestic product (GDP) and slightly less than 5% of total tax and social contribution revenues in the EU-28 in the last several years. Ultimately, the aim of energy taxes is to minimize negative impacts on the environment and ensure their rational use by facilitating a shift towards more sustainable consumption patterns. However, energy taxes increase the price of electricity, which can have unfavorable consequences for low income households in particular. Since energy taxes are also an important source of government income, their optimal level is important but difficult to be determined.

Eurostat data [4] show that electricity consumption by households fell by about 1% in the period from 2005 to 2016. This drop is desirable from the environmental point of view, but an increase in energy poverty also caused by high electricity bills has been observed in the same period. Clemente [6] demonstrated that even in richer EU countries electricity has become a luxury good. According to the Eurostat data on energy [4], the EU-28 average electricity price was EUR 0.2 per kWh in the period 2005–2016. In the same period, the EU average electricity price and energy tax increased by 3.3% and 2.35% per year, respectively. Besides, the household sector participated with the average of 48% in total energy tax revenues paid by all energy sectors [4]. Moreover, the movements in the implicit tax rate on energy, defined as the ratio of energy tax revenues to final energy consumption, from 193.88 EUR per ton of oil equivalent (toe) in 2005 to 234.79 EUR per toe in 2016 [4], additionally point to an increasing issue of energy poverty. The energy policy authorities have to determine economically efficient, environmental effective and socially acceptable policy instruments.

To find optimal energy taxation and effectively leverage this instrument, it is important to understand how energy tax changes affect residential electricity consumption. As stated by Alberini and Filippini [7], the effectiveness of an electricity policy depends upon the price elasticity of electricity demand. If electricity demand is price-inelastic, energy taxes could be efficient from the government budget point of view. By contrast, it would be inefficient from the environmental and social point of view and hence they would not contribute to the achievement of the EU energy policy targets. Bearing the above in mind, it is necessary to create a multivariate research framework for exploring the effects of energy taxes on residential electricity consumption. It should include not only economic and institutional variables, but also social and contextual variables as the explanatory variables.

Besides, the movements in electricity consumption may be caused by the movements in income or GDP per capita. In most cases, theoretical and empirical findings confirm the relationship between electricity consumption and GDP, what cannot be said for the direction of causality (for a review, see [8,9]). However, regardless of this direction, a wise use of electricity cannot hinder GDP growth. Recently, several studies have started to consider energy consumption as an indicator of overall environmental pressure and hence conducted research aiming to test the relationship between energy consumption and GDP [10–14] or electricity consumption and GDP [15,16] within the so-called environmental Kuznets curve (EKC). Although some of them have confirmed its existence [10,13–16], and therefore that the environmental quality deteriorates at early stages of economic growth and subsequently improves at later stages, their results are inconclusive in general and call for new research.

The aim of the present paper is twofold. First, it aims to directly investigate the effects of energy taxes on residential electricity consumption by incorporating the energy tax variable into the empirical model, and indirectly through the own and cross price and income elasticity of household demand for electricity for 28 EU member countries in the period 2005–2016. Second, it attempts to test the validity of the residential electricity environmental Kuznets curve (EEKC) in a multivariate framework to find out whether a continuous increase in GDP per capita in EU countries will tend to decline electricity consumption and hence environmental pressures at some point in time.

Sensitivity of electricity demand to prices and income has been extensively studied (see [17]). However, studies aiming to directly explore the efficiency of energy taxes are missing, particularly those based on the EEKC hypothesis. Namely, the existing studies are largely based on empirical analysis of household response to electricity price changes without considering the EKC (e.g., [7]), or doing that but not considering energy taxes (e.g., [14]), or considering taxes but not the price elasticity within the framework of the EKC (e.g., [18,19]). The present paper aims to close this gap by examining the effects of energy taxes and selected socio-economic and contextual variables including the price and income elasticity of residential electricity demand thereon within the context of the EEKC. To that end, a dynamic panel analysis is conducted.

The paper provides three distinctive contributions. First, it directly and indirectly explores the effects of energy taxes on residential electricity consumption. Given that, energy taxes turn out to be an inefficient policy instrument for a direct influence on residential electricity consumption. By contrast, as a policy-induced part of electricity prices, they have a statistically significant influence thereon. Second, it tests the validity of the EEKC in a multivariate setting and a system generalized method of moments (SYS-GMM) framework, and confirms its validity. Third, it shows that electricity consumption is highly dependent on its past behavior, which is in turn determined by the previous economic situation, electricity-related behavior and electricity practices in using technologies. Since acquired habits and practices in consumption cannot be quickly changed, education may play an important role therein. By contrast, income poverty does not significantly influence electricity consumption.

The remainder of the paper is organized as follows. Section 2 describes the theoretical foundation underlining the energy-related environmental taxes and the residential electricity consumption–development relationship. It also reviews the previous findings related to the research subjects. Section 3 introduces the data and methods used in estimating the empirical residential electricity consumption functions. Section 4 presents and discusses the results obtained. Section 5 provides the summary of findings, recommendations and concluding remarks.

2. Contextual Background with a Literature Review

In the literature, the theoretical foundation underlining energy-related environmental taxes and their effects on an economy and environment is intensively discussed (e.g., [20]) as well as the related empirics (for a survey, see [21–24]).

Energy tax is introduced to compensate for market failures such as negative externalities generated by economic activities and ensure an increase in government revenues. In the last twenty years, its introduction was also motivated by the need to decrease environmental impacts by lowering energy consumption and increase energy security by redirecting energy use towards a less-dependent energy supply structure. For an overview of the reasons behind energy tax introduction, see [25–27]. Sterner and Koehlin [5] revealed that environmental taxation seems to have a more prominent role in Europe than in other countries, partially due to greater reliance on and acceptance of taxes and possibly a larger public sector in general, as well as more ambitious energy and environmental goals. Kosonen and Nicodeme [28] examined the role of fiscal instruments in energy and environmental policies in the EU. They highlighted that fiscal instruments such as taxation can play an important role in achieving the EU energy targets alone or in complementing other market-based instruments and regulatory measures, particularly when environmental damages are not location-specific and do not vary with the source of pollution.

In competitive markets, described by neoclassical microeconomic theory, taxation influences volumes and society suffers an efficiency loss which should be compared to the benefits obtained by taxation. This is because taxation constrains the effects of the market mechanism, which commonly leads to a Pareto optimal allocation of production factors. In the early 1920s, according to Bye and Bruvoll [25], Franck Ramsey already said that such taxation should be put on the least elastic goods to minimize the efficiency losses. Since energy goods generally show a low elasticity of demand [17], they are considered as suitable goods for taxation.

The theoretical, efficiency-related basis for energy taxes is to be found in the theory of optimal taxation [27] which aims to minimize welfare losses through a second best tax structure. According to this theory, any tax (except lump-sum alternatives) influences the behavior of individuals, leads to distortions of market behavior and reduces welfare. It generates thereby two effects: an income redistribution effect (a transfer of money between the private and public sectors and wealth worsening, particularly of lower income households) and a substitution effect (favoring the consumption of goods that are cheaper, i.e., less affected by taxation).

However, in addition to fiscal benefits, corrections of negative externalities and imperfectly competitive market positions as well as insurance of environmental and energy security have become important arguments for taxing energy production and consumption. In the early 1920s, Arthur C. Pigou already pointed out that taxes (more precisely, a direct tax on carbon emissions) to internalize negative externalities (i.e., carbon dioxide (CO_2) abatement) could be used as the most efficient tax instrument observed [25]. From the welfare theory point of view, this is true and environmental taxes are an effective and efficient instrument that can be used for that purpose [29]. Most empirical research has corroborated that an increased environmental tax may have beneficial effects on the environment (for a review, see [21]; see also [18]).

In the 1990s, the double-dividend hypothesis emerged. It states that it is possible to achieve a double benefit, i.e., environmental and economic, by imposing (or increasing) an environmental tax and, at the same time, reducing other taxes, keeping the same government revenues. Freiere-Gonzales [24], who carried out a survey including a statistical and a meta-regression analysis of the empirical literature related to this topic, demonstrated that empirical research corroborated the environmental effect, what cannot be clearly said for the size of the fiscal/economy effects.

Using cross-sectional regression and panel dynamic regression, Miller and Vela [30] examined the effectiveness of environmental taxes for 50 countries from all world regions for the period 1995–2010. They found that countries with higher revenues from environmental taxes exhibit higher reductions in CO_2 emissions, particulate matter (PM_{10} emissions, and energy consumption and production from fossil sources. Morley [18] studied the relationship between environmental taxes and pollution as well as energy consumption by employing a dynamic panel analysis for EU countries and Norway for the period 1995–2006. He has unveiled a significant negative relationship between environmental taxes and pollution, but no relationship between environmental taxes and energy consumption. The latter implies, as he underlined, that pollution is being reduced through the use of cleaner technologies. Besides, he failed to confirm the validity of the EKC.

However, although energy taxes or environmental taxes in general may generate the double dividend, i.e., a cleaner environment and revenues that can be used to reduce distortionary taxes, they may generate unfavorable consequences at the same time. For example, such consequence is the regressive effect on income distribution [31]. Namely, energy products are generally necessary goods, and an increase in price of such goods induced by energy taxes particularly burdens households with lower incomes.

The Organization for Economic Co-operation and Development (OECD, [32]) has also stressed that taxation already provides a useful environmental policy instrument, but that its use could be made more effective. However, two policy concerns prevent its usage more widely. First, there is a concern that energy taxes will lessen the international competitiveness of some sectors and hence lead to losses of jobs and revenues since their rates vary widely from country to country. Second, an increase in existing energy taxes or an introduction of new ones may have an adverse distributional effect and intensify energy poverty. Oueslati et al. [33] examined the relationship between energy taxes and income inequality for 34 OECD countries from 1995 to 2011. They have showed that the size and direction of the relationship between the share of revenues from energy taxes in GDP and income inequalities depend on the presence of explicit tax revenue recycling mechanisms.

The literature has also shown a particularly growing interest in explaining the relationship between environmental pressures and income level during the last decade. Namely, in the early

1990s, income inequality was related to environmental degradation, and Grossman and Krueger [34] were the first to empirically demonstrate that the relationship between environmental degradation and economic growth has an inverted U-shape. This finding led them to the conclusion that environmental quality deteriorates at early stages of economic growth and subsequently improves at later stages. This hypothesis was called the EKC after Simon Kuznets, who asserted in the 1950s that income distribution and income level can be described by an inverted U-curve.

Since then, many empirical studies have been conducted to test the presence of the EKC. Some of them were focused on European countries and provided evidence of its presence (e.g., Auci and Trovato [35] for 25 EU countries for the period 1997–2005; Lapinskiene et al. [19] for 20 EU countries for the period 2006–2013), while some of them failed to do that (e.g., Mazur et al. [36], who did not confirm the existence of the EKC for all 28 EU countries, but only for 16 older EU countries for the period 1992–2010).

Instead of using the amount of pollutants or the level of GHG emissions as indices for environmental pressures, empirical studies have recently started to use the level of energy or electricity consumption as an indicator of an overall environmental pressure [10–16]. This paper follows them. This is because energy consumption is a source of several environmental problems, as Suri and Chapman [10] underlined. Kounetas [37] found that energy consumption accounts for approximately 80% of anthropogenic GHG emissions in the EU, while several studies around the world also corroborated that household electricity use is directly responsible for significant GHG emissions (e.g., [38,39]).

Suri and Chapman [10], who conducted one of the early research into the energy EKC, confirmed its existence for the commercial sector for 33 countries in all parts of the world over the period 1971–1991. They also investigated the impact of imports and exports of manufactured goods on the EKC by means of pooled cross-country and time-series data. Luzzati and Orsini [11] examined the energy EKC for 113 countries over the period 1971–2004. They used carbon dioxide emission as the dependent variable and real GDP per capita, population and industry share as the independent variables. They concluded that the estimates cannot support its existence. The same conclusion was drawn by Pablo-Romero and de Jesus [12], who examined the energy EKC for the Latin America region for the period 1990–2011, while Aruga [13] found evidence that the energy EKC hypothesis sustains for the whole Asia-Pacific region for the period 1984–2014. Morley [18] did not find any evidence that GDP per capita in both linear and nonlinear forms had the expected nonlinear effect on energy consumption in the EU for the period 1995–2006. By contrast, Pablo-Romero and Sanchez-Brada [14] provided evidence on the existence of the residential energy EKC for EU-28 countries in the period 1990–2013. They used the share of urban population in total population as a control variable and a multilevel mixed-effects model for parameter estimation.

In general, there is little evidence for the relationship between the electricity-development linkages as well as the effect of energy taxes and other explanatory variables on residential electricity consumption. Exploring the relationship between environmental pressures, i.e., residential electricity consumption, economic development and energy-related environmental taxes within the framework of the EEKC hypothesis, the present paper complements previous research. However, it also expands knowledge by examining not only the direct effect of energy taxes within the EEKC on residential electricity consumption which is an important source of environmental degradation, but also indirect effects through electricity and gas prices. Additionally, exploring the effects of economic, institutional, sociological and contextual determinants of electricity consumption requires an integrated approach which is often overlooked in research in this field.

3. Data and Methods

3.1. Data

To achieve the aims of the paper, the following empirical panel data model was set:

$$electricity_{it} = f(Y_{it}, P_{el}, P_{gas}, tax_{it}, educ_{it}, poverty_{it}, climate_{it}, recession_{it}) \quad (1)$$

where Y_{it} denotes real GDP per capita for the country i (i = 1, …, 28) in the year t (t = 2005, …, 2016). $electricity_{it}$ refers to residential electricity consumption per capita, P_{el} stands for electricity prices for medium-sized households with annual consumption ranging between 2500 kWh and 5000 kWh, and P_{gas} stands for natural gas prices. They are defined as the average national price in euro per gigajoule (GJ) including taxes and levies applicable for the first semester of each year for medium-sized households (consumption band D2 with annual consumption between 20 and 200 GJ). Until 2007, the prices referred to the status on 1 January of each year for medium-sized consumers (standard consumer D2 with annual consumption of 83.70 GJ). Natural gas is considered as an alternative fuel. tax_{it} denotes energy taxes which reflect the total energy tax revenues as already mentioned. They entered the model as a percentage of GDP. $educ_{it}$ stands for tertiary education and captures the percent of population from 15 to 64 with tertiary education. Finally, $poverty_{it}$ represents the at-risk-of-poverty rate, which is defined by Eurostat as the percentage of population with an equalized income below the risk-of-poverty threshold, set at 60% of the median equalized income after social transfers.

A set of explanatory variables also includes two variables represented in the form of a dummy variable, i.e., climate conditions ($climate_{it}$) and recession ($recession_{it}$). Both variables are time variant. Most recent studies use heating and cooling degree days to account for climate conditions. We follow Lechtenboehmer and Schuering [40], who distinguished between warm, moderate and cold climate zones, where a warm climate zone has fewer than 2200 heating and cooling degree days (HCDD), a moderate climate zone between 2200 and 4200 HDD, and a cold climate zone more than 4200 HDD. The recession dummy variable was included into models to capture the business cycle effect.

Summary information on the data is given in Table 1 (the first column). All data were provided by Eurostat, with the exception of the price deflator whose source is the International Monetary Fund (IMF, [41]). The price deflator was used to deflate the nominal variables, i.e., to remove the effect of inflation therefrom. The logarithmic values of the following variables are used in further analysis: electricity consumption per inhabitant, real GDP per inhabitant, real electricity and natural gas prices. The paper uses panel data which observe the behavior of EU countries across time. The panel is unbalanced. Each country has its own specificities (individual effects) and hence the panel econometric technique is well suited to the aim of this paper.

Table 1. Descriptive statistics.

Variable	Symbol	Obs	Mean	Std. Dev.	Min	Max	VIF
Household electricity consumption (kWh per capita; tsdpc310, tps00001)	*electricity*	336	1650.64	842.04	431.85	4.922.77	
Real GDP per capita (const EUR; tec00001)	*Y*	336	24,873.38	16,480.54	4181.50	84,368.38	3.62
Electricity prices for medium-sized households (const EUR_centi per kWh; ten00117)	P_{el}	336	15.68	5.10	6.88	29.16	4.08
Natural gas prices for medium-sized households (const EUR per GJ; ten00118)	P_{gas}	292	15.358	5.95	5.10	35.90	3.28
Education—% of population from 15 to 64 with tertiary education (edat_lfs_9903)	*educ*	336	23.55	7.40	9.1	39.6	1.67
Recession dummy (1 if real GDP fell in the current year compared with the previous one; 0 otherwise; tec00001)	*recession*	336	0.24	0.43	0.00	1.00	1.08
Climate conditions (1 if a country has more than 2200 HDD; 0 otherwise; nrg_chdd)	*climate*	336	0.095	0.29	0.00	1.00	1.20
Energy taxes (% of GDP; env_ac_tax)	*tax*	336	1.91	0.42	1.11	3.13	1.14
At-risk-of poverty rate (%; ilc_peps01)	*poverty*	331	16.307	3.830	8.6	26.4	1.44

Source of data: Eurostat [5]; Note: The Eurostat's code for initial time series is given in brackets.

3.2. Methods

The general linear regression model with panel data can be represented as Equation (2) (see [42]):

$$y_{it} = \alpha + \beta X_{it}^{'} + \varepsilon_{it}, \tag{2}$$

where i and t represent an individual (i = 1, …, N) and a period (t = 1, …, T), respectively. Y_{it} is a dependent, endogenous variable. $X_{it}^{'}$ is a K-dimensional row vector of explanatory variables (K is their total number). α is an intercept and β is a K-dimensional column vector of parameters to be estimated. Errors are independent and identically distributed, with the usual properties, mean 0, uncorrelated with themselves, uncorrelated with X and u_i and homoscedastic, i.e., $\varepsilon_{it} \sim IID(0, \delta^2_{\varepsilon})$.

There are two types of panel models represented by Equation (1): the fixed effects model and the random effects model, assuming unobservable random variables that could be correlated to other regressors, or are not correlated to any, respectively. Hausman's specification test is used to choose between these two model types. It compares two estimators under the null hypothesis of no significant difference. If the null is not rejected, the more efficient random effects estimator is chosen.

Moreover, there is a dynamic panel model that aims to incorporate into estimation the relations of causality generated within the model as a way of dealing with the endogeneity issue (see Baltagi [42]). This paper uses a dynamic panel model with the SYS-GMM estimator that enables capturing the dynamic nature of residential electricity consumption by including the dependent variable also as a lagged variable among the regressors. Thus, in a dynamic framework, Equation (2) can be specified as follows (see [42]):

$$y_{it} = \alpha + \lambda y_{it-1} + \beta X_{it}^{'} + \varepsilon_{it}, \tag{3}$$

where λ is a parameter of the lagged dependent variable, and i = 1, …, N; t = 1, ..., T. GMM estimation is based on the first difference transformation of Equation (3) and the subsequent elimination of individual-specific effects [42]:

$$\Delta y_{it} = \lambda \Delta y_{it-1} + \beta \Delta X_{it}^{'} + \Delta \varepsilon_{it}, \tag{4}$$

where Δ is the first difference operator, i = 1, …, N; t = 1, ..., T. Thus, two equations, one in level and one in the first difference, are estimated simultaneously. The equation in levels is instrumented with lagged differences, and the equation in differences is instrumented with lagged variables (at least twice) in levels. In addition to the usual goodness-of-fit measures (such as the F test), the estimated dynamic model may be evaluated by employing two tests: the Sargant test (or the Hansen J test in robust estimation) to check the validity of the instruments with the null hypothesis that all instruments are exogenous as a group, and the Arellano–Bond second-order serial correlation ($AR(2)$) test to check the hypothesis that the error term is serially uncorrelated. More details on panel data analysis are given in Baltagi [42]. To conduct a static and dynamic panel analysis, the user-written *xtbond2* command by Roodman [43] in Stata 13.0 on Microsoft Windows is used in this paper.

Due to benefits generated by the dynamic panel model with the SYS-GMM estimator (e.g., resolving the issue of unobserved cross-section heterogeneity, omitted variable bias, measurement error and potential endogeneity that may affect parameter estimation), it has already been used in empirical research of consumer determinants (e.g., [44]).

4. Results with Discussion

4.1. Results of Preliminary Analysis

Descriptive statistics (Table 1) reveal that there are wide varieties in the observed variables across EU-28 countries. This can be seen in the wide range between the minimum and maximum values. Electricity consumption varies significantly across countries, whereby more developed EU countries use more electricity than less developed, Central and Eastern EU countries. Usually, electricity prices and natural gas prices are smaller in the latter as well as the share of highly educated people in total population, while the percentage of people at risk of poverty is higher.

Before conducting panel data analysis, the selected panel data have to be examined by unit root tests since the applied panel method assumes the stationarity in a panel dataset. In this paper, stationarity is tested by the Levin–Lin–Chu test. Exceptions are the panel datasets for natural gas prices and the at-risk-of-poverty rate. Since these panel datasets are unbalanced, the Fisher-type Phillips–Peron (PP) unit root test is used for the same purpose. To mitigate the effect of cross-sectional correlation which may appear because EU countries share some similarities, the version of the test in which the removed cross-sectional means was employed. Table A1 in the Appendix A shows the results for the variables included in the analysis. The null hypothesis that the panels contain unit roots at levels can be rejected at a 5% critical value for all of them, meaning that the series are stationary.

As shown in Table A2 in the Appendix A, the dependent variable is not strongly correlated with the explanatory variables, reducing the possibility that the regression results would be inconsistent and biased. Nevertheless, we use panel regression models with a robust standard error to account for the possible problem of heteroskedastic and autocorrelated error structure. Moreover, the correlation coefficients indicate that multicollinearity should not be an issue in panel analysis even between the energy tax rate and electricity price variables. This is additionally confirmed by the variance inflation factors (VIF) (see Table 1, the last column).

4.2. Regression Results with Discussion

To explain the residential electricity consumption–development relationship within the EU, panel data for the period 2005–2016 are used. The explanatory variables reflect a socio-economic, institutional and contextual context. Different static and dynamic panel models were run with robust standard error. Models 1–4 refer to the static panel regression models, while Models 5 and 6 refer to the dynamic panel regression models. The instruments include the first lags of the explanatory variables in both transformed and untransformed form, whereby the lagged dependent variable was instrumented up to the third lag in the dynamic panel models.

Moreover, as is common in the literature on the EKC, several model variants (Models 1, 2, 4, and 6) include both linear and nonlinear squared form of real GDP per capita. Table 2 gives the estimation results of different econometric model specifications.

Considering the model diagnostic tests, all models fit the reality in a satisfactory way. The values of R^2 indicate that the more complex static panel models account for more than 55% of variance of residential electricity consumption, while F statistics indicate the models are correctly specified. Hausman tests were used to detect which static panel model specifications are more appropriate. Their results are presented in Table 2. With respect to the dynamic panel models, the Hansen J test statistics of overidentifying restrictions is satisfactory in both cases, suggesting that the instruments used in regressions are valid and the models are correctly specified. Besides, the tests for $AR(2)$ errors reveal the models have no second-order autocorrelation which may cause the inconsistency of the SYS-GMM estimate. Moreover, the number of instruments does not exceed the number of groups. Bearing also in mind the benefits of using the SYS-GMM model, we consider particularly the estimated coefficients from this technique to be the most reliable. The dynamic panel models recognize past behavior of electricity consumption, real GDP per capita, real electricity prices and climate conditions as well as the share of highly educated people in GDP as important determinants of residential electricity consumption in the EU under the period of study.

Table 2. Estimation results: static and dynamic panel regression models.

Model Type	Model 1: Fixed		Model 2: Fixed		Model 3: Random		Model 4: Random		Model 5: Dynamic		Model 6: Dynamic	
Variable	Estimated Coefficient	Robust St.err.	Estimated Coefficient	Robust St.err.	Estimated Coefficient	Robust St.err.	Estimated Coefficient	Robust St.err.	Estimated Coefficient	Robust St.err.	Estimated Coefficient	Robust St.err.
electricity $(t-1)$									0.917 *	0.037	0.856 *	0.058
Y	2.797 *	0.988	2.699 **	1.010	0.333 *	0.071	2.151 **	1.037	0.034 ***	0.019	1.620 **	0.593
Y^2	−0.137 **	0.051	−0.131 **	0.052			−0.094 **	0.053			−0.078 **	0.029
P_{el}					−0.186 *	0.063	−0.177 *	0.062	−0.064 *	0.020	−0.131 *	0.039
P_{gas}					0.046	0.045	0.041	0.048	0.019	0.024	0.027	0.033
recession					0.018 **	0.008	0.015	0.009	0.015	0.010	−0.005	0.007
climate					0.063 *	0.017	0.069 *	0.019	0.039 *	0.016	0.058 **	0.028
tax			0.021	0.022	0.082 **	0.039	0.077 ***	0.041	0.003	0.009	0.023	0.034
poverty					0.000	0.004	0.001	0.004	0.000	0.001	0.001	0.002
educ					0.001	0.003	0.001	0.003	0.000	0.001	−0.001 ***	0.001
const	−6.875	4.913	−6.572	4.937	4.144 *	0.700	−4.558	5.078	0.376	0.221	−7.133 **	2.828
Number of obs.	336		336		287		287		264		264	
Number of groups/ Instruments	28		28		25		25		25		25	
R^2-between	0.277		0.358		0.583		0.594					
Wald χ^2 *F*-test	$F(2, 27) = 4.68$; $p = 0.018$		$F(3, 27) = 3,85$; $p = 0.020$		*Wald* $\chi^2(8) = 37.44$; $p = 0.000$		*Wald* $\chi^2(9) = 38.56$; $p = 0.000$		$F(9, 24) = 1173.77$; $p = 0.000$		$F(10, 24) = 267.97$; $p = 0.000$	
AR(*1*)									$Z = -2.44$; $p = 0.015$		$Z = -2.59$; $p = 0.010$	
AR(*2*)									$Z = 1.62$; $p = 0.105$		$Z = 1.31$; $p = 0.190$	
Hausman test/Hansen *J* test	Hausman test: 14.47; $p = 0.001$		Hausman test: 11.04; $p = 0.012$		Hausman test: 1.41; $p = 0.994$		Hausman test: 10.02; $p = 0.349$		Hansen *J* test: $\chi^2(15) = 19.47$ $p = 0.193$		Hansen *J* test: $\chi^2(14) = 18.74$: $p = 0.175$	

Note: *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively. St.err. = standard error.

Traditionally, it is assumed that there is a significant relationship between GDP and electricity consumption [8,9]. This paper confirms that real GDP per capita, which reflects the level of development and household income, is an important determinant of household electricity consumption in all model specifications. The positive sign indicates that its increase leads to an increase in the dependent variable, holding everything else constant. This may be a consequence of the rebound effect, which assumes that improvements in technical efficiency in the use of electricity caused by higher GDP leads to an increase in demand for energy. The negative sign of real GDP per capita squared suggests the EEKC hypothesis holds even in the multivariate environment (Models 4 and 6). This means that there is a non-linear relationship with a maximum point from which an increase in real GDP per capita will no longer be followed by an increase in electricity consumption, i.e., environmental degradation. After that point, its increase will tend to reduce electricity consumption and hence environmental degradation. These results are in line with the findings of Pablo-Romero and Sanchez-Brada [14], who have unveiled the existence of the residential energy EKC for the EU-28 for the period 1990–2013.

The share of energy tax revenues in GDP turn out to be positive but not significant in the dynamic panel model settings, meaning that energy tax is not an effective policy tool for influencing directly residential electricity consumption. This can be a consequence of its unequal distribution across EU countries and the government efforts to mitigate its negative effects on low income households by using different subventions, exemptions or reduction schemes.

Inefficiency of energy or environmental taxes in general in European countries has already been implicitly observed (see Ekins and Speck [45] for the Western European countries in the 1990s or Morley [18] for EU countries and Norway for the period 1995–2006. However, Lapinskiene et al. [19] revealed that higher energy taxes together with research and development and the number of sustainable enterprises decreased the level of greenhouse gases in 20 EU countries during 2006–2013.

In contrast to energy taxes, real prices of electricity have a statistically significant and negative influence on residential electricity consumption, what is consistent with traditional economic theory. This also means that energy taxes, which have a direct effect on the policy-induced component of electricity prices, may influence indirectly, but in that way more efficiently, residential electricity consumption. The price elasticity of electricity demand, known also under the name own price elasticity, reflects the sensitivity of household demand to the price of electricity. Its estimated values in Table 2 indicate a very low price elasticity, i.e., around −0.1. Evidently, household electricity demand is price-inelastic in the short-run and this is consistent with numerous studies. For example, for the period 1995–2007, Alberini and Filippini [7] estimated the short- and the long-run own price elasticity for 48 US states to amount between −0.08 and −0.15 and between −0.44 to −0.73, respectively. Azevedo et al. [46] found that the short price elasticity was −0.2 for the EU in the period 1990–2004.

Covering the period 1947–1997, Espey and Espey [47] carried out a meta-analysis for residential electricity demand from around the world and unveiled that the short- and the long-run price elasticity amounted to −0.35 and −0.85, respectively. Labandeira and coworkers' [17] meta-analysis of studies, also from around the world, reports a lower mean short-run price elasticity of electricity demand of –0.21 and a mean long-run elasticity of –0.67 for the period 1990–2014.

This paper shows that the own long-run price elasticities hover around −0.85 (−0.8 in Model 5 and −0.9 in Model 6). They were calculated by dividing the estimated short-run own price elasticity by the estimate on one minus the estimated value of the lagged dependent variable. Thus, by comparing our results to others, we estimate a similar short-run price elasticity of electricity demand and a little higher long-run price elasticity. The latter can be explained by the fact that this paper is focused on the EU which is strongly committed to accomplishing the energy targets for 2020 and 2030 by supporting environmental investment and energy efficiency improvements as well as the usage of more energy saving and environmentally friendly products and improvements.

Statistical significance of the electricity price variable indicates that its level and structure should be considered and used as a valuable socio-economic and energy policy tool for developing more effective electricity pricing schemes, as observed by Filipovic et al. [48]. However, a very low price elasticity of electricity indicates that, at least in the short-run, energy policy will not be effective from the environmental and social point of view. This means that households will not have much incentive to invest in electricity efficient or electricity conservation innovations to reduce electricity consumption in the case of an electricity price increase in the short-run. However, in the long-run, faced with an increase in electricity prices, households are more likely to invest in these innovations to lower their electricity bills. Evidently, electricity consumption needs time to be adjusted according to changes in the environment.

The cross price elasticity, i.e., elasticity of electricity consumption on gas prices, is positive, suggesting there is a substitution relationship between electricity and gas. However, this relationship is not statistically significant in either of the model variants.

Espey and Espey [47] observed that electricity affordability risk is more pronounced in countries with lower real GDP per capita, while Auci and Trovato [35] and Mazur et al. [36] have corroborated that some areas within Europe, particularly in Central Eastern and South Europe, are also deprived of access to a secure supply of clean and affordable energy, and that their choice of fuel is more limited. Pye et al. [49] estimated that nearly 11% of the EU's population is in such situation, while Borozan [44] revealed a statistically significant effect of the at-risk-of-poverty rate on residential energy consumption across EU regions. However, this variable turned out to be an insignificant determinant of residential electricity consumption in this study. It seems that differences observable at the EU regional level related to poverty tend to be neutralized at the aggregated level. Additionally, the reason could be the fact that this study investigates electricity consumption but not total energy consumption of the residential sector. Further research should explore more deeply the reasons therefor.

Since recession leads to unemployment and poverty, it also increases uncertainty on future income and its stability. Consequently, the dynamic panel models show that countries stuck in recession have lower residential electricity consumption than those in expansion. However, the recession variable does not have a statistically significance effect thereon, which is inconsistent with Bertoldi et al. [50] or Borozan [44], who have observed this influence in the EU.

Climatic conditions turn out to be statistically significant in both dynamic panel models; probably because the large part of energy is used for space heating. Colder weather will increase electricity consumption more than warmer weather, as pointed out by Kavousian [51] or Borozan [44].

The paper shows that current residential electricity consumption behavior is also determined by its past behavior, confirming thereby its dynamic and universal nature as well as the application of the dynamic panel method. This dependence has already been noticed in the literature [44]. Judging by the estimated coefficient values, the lag of electricity consumption has the largest impact on electricity consumption. The previous economic situation together with created electricity-related behavior and electricity practices in relation to using technologies are obviously important in determining future behavior.

Almeida et al. [52] highlighted that behavioral changes are one of the most effective ways for reducing electricity consumption in the residential sector. Since acquired habits and practices in consumption cannot be quickly changed, education may play an important role therein. This paper corroborates its statistical significance in the dynamic settings and suggests a larger share of highly educated people in total population and smaller electricity consumption, holding everything else constant. More educated people are more prone to use modern energy saving appliances and energy saving innovations in general. On the other hand, they usually have higher disposable income and better financial capacities to realize energy reduction and the energy efficiency improvement potential than less educated people or poorer people. However, the estimated coefficient for the education variable is very low. Moreover, the other estimated panel models suggest its statistically positive but insignificant influence and therefore a possible rebound effect. The favorable effect of tertiary education on electricity consumption must therefore be strengthened by policy measures, such as fostering intensive awareness-raising programs on electricity appliance labels or green energy and energy efficiency educational workshops and programs in schools. Other studies have also found a significant effect of education level on pro-environmental behavior and/or energy use (e.g., [53]), while others have identified a statistically weak or insignificant one (e.g., [54]). Almeida et al. [52] estimated that the potential electricity savings that can be implemented by existing technologies and improved behavior can reach 48% in the European residential sector.

To summarize, since residential electricity demand is price-inelastic in the short run, energy policy makers need to design a set of measures which will have short-run and long-run effects. Thus, they have to combine different regulations (e.g., stronger building codes and more demanded appliance standards) and financial schemes and incentives with informational, educational and awareness-raising programs and measures. An example for that is equipping households with intelligent metering systems or organizing green energy and electricity efficiency campaigns targeted to change consumer behavior and practices used. On the other hand, they have to stimulate research and development in this area because a new and more efficient electricity technology is needed. Further research should show how a combination of these policy programs and measures as well as a changing mix of electricity sources towards more green sources will affect the expected residential electricity development path.

5. Conclusions

Energy policy authorities have to determine economically efficient, environmentally effective and socially acceptable policy instruments to accomplish energy targets. To that end, the EU has used several energy policy instruments and adopted several measures including energy taxes, which this paper is based on. Energy taxes burden the prices of energy products such as fuel, transport and electricity. For example, their proportion amounts to about a third of final electricity prices by households in the EU. In the last several years, on average, energy tax revenues have accounted for slightly less than 2% of GDP and slightly less than 5% of total tax and social contribution revenues.

Eurostat data show that households account for approximately 30% of final electricity consumption and 25% of final energy consumption. Besides, the household sector has participated with the average of 48% in total energy tax revenues paid by all energy sectors, confirming thereby its important role in accomplishing the EU energy targets and a particular interest in this research. In the period from 2005 to 2016, household electricity consumption fell by about 1%. This drop is desirable from an environmental point of view, but an increase in energy poverty caused also by high electricity bills has been observed in the same period.

The present paper has aimed: (i) to directly explore the effect of energy taxes on residential electricity consumption by incorporating the energy tax variable into the model, and indirectly through the own and cross price and income elasticity of household demand for electricity; and (ii) to test the validity of the household EEKC in the multivariate setting and SYS-GMM framework for 28 EU member countries in the period 2005–2016.

Energy tax revenues turned out to be an inefficient policy instrument for directly influencing electricity consumption due to different subventions, exemptions or reduction schemes applied across the EU. However, as a policy-induced part of electricity prices, they statistically significantly and negatively influence residential electricity consumption. Household electricity demand is price-inelastic in the short-run, what makes policy price incentives directed to reduce consumption ineffective. By contrast, in the long-run, households are more likely to invest in energy efficient and/or energy conservation innovations as a response to an electricity price increase.

As for the EEKC, the paper corroborated its inverted U-shaped form, assuming thereby at least the same level of policy efforts directed to accomplish energy targets and household willingness to use goods in an environmentally friendly way. Further research should determine the maximum amount after which an increase in GDP will lead to a decrease in residential electricity consumption. The paper also provided evidence that electricity consumption is highly dependent on its past behavior, which is in turn determined by the previous economic situation, electricity-related behavior and electricity practices in relation to using technologies. Since acquired habits and practices in consumption cannot be quickly changed, education may play an important role therein.

By contrast, income poverty does not significantly influence electricity consumption. Nevertheless, energy poverty exists in the EU to some extent and the redistribution effect of energy taxes needs to be carefully considered.

From an energy policy point of view, the results obtained using the dynamic panel models imply that a price-based policy may be effective in discouraging residential electricity consumption only in the long-run since electricity consumption needs time to be adjusted according to changes in the environment. However, energy policy should not rely only on this instrument to foster a transition of the EU economy to a low-carbon and energy efficient economy. Given the importance of the EEKC, this paper revealed that it should foster investment in human capital which leads to economic growth and development as well as energy efficient and pro-environmental behavior in general.

However, descriptive statistics demonstrate that there are considerable socio-economic and institutional differences between EU countries that reflect themselves to different electricity consumption patterns. This paper does not consider these, but they should be carefully analyzed in further research and the results obtained should be considered when formulating the EU energy policy mix. Additionally, this paper examines the residential electricity consumption–development relationship within the EU. However, electricity consumption is only one type of energy used by the residential sector; further research should explore whether this relationship would be different if total residential final energy consumption or some other types were considered in a multivariate setting.

Funding: This paper was supported by the Croatian Science Foundation under Grant number IP-2013-11-2203.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Levin–Lin–Chu unit root test results.

Variable	Constant Only	Included Trend
electricity	−4.8361 (0.000)	−3.9344 (0.000)
Y	−13.1996 (0.000)	−16.5601 (0.000)
P_{el}	−4.5705 (0.000)	−10.2379 (0.000)
P_{gas} *	101.3548 (0.000)	70.4396 (0.045)
educ	−5.4527 (0.000)	−11.0494 (0.000)
tax	−3.9640(0.000)	−11.1558 (0.000)
climate	−5.2641 (0.000)	−2.7637 (0.003)
recession	−5.7766 (0.000)	−4.1718 (0.000)
poverty *	115.3862 (0.000)	102.1867 (0.000)

Note: *p* values are given in parenthesis. H0 for the Levin–Lin–Chu test: panels contain unit roots. * The stationarity is tested by the Fisher-type Phillips–Peron unit root test. Its statistics refers to inverse chi-squared. H0 for this test: all panels contain unit roots.

Table A2. Pearson correlation coefficients.

	Electricity	*Y*	P_{el}	P_{gas}	*Tax*	*Poverty*	*Educ*	*Climate*	*Recession*
electricity	1.000								
Y	0.681 *	1.000							
P_{el}	0.318 *	0.691 *	1.000						
P_{gas}	0.619 *	0.653 *	0.788 *	1.000					
tax	−0.077	−0.204*	−0.049	0.016	1.000				
poverty	−0.449 *	−0.47 *	−0.358 *	−0.378 *	0.020	1.000			
educ	0.503 *	0.526 *	0.294 *	0.342 *	−0.117 *	−0.108 *	1.000		
recession **	0.003	0.065	0.177 *	0.171 *	−0.021	0.074	0.001	1.000	
climate **	0.528 *	0.169 *	−0.032	0.229 *	0.051	−0.144 *	0.294 *	0.028	1.000

Note: * indicates significance at the 5% level. ** denotes the point-biserial correlation coefficient.

References

1. European Commission. *Energy 2020: A Strategy for Competitive, Sustainable and Secure Energy*; 10.11.2010 COM(2010) 639 Final; European Commission: Brussels, Belgium, 2010.
2. European Commission. *A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*; 8.3.2011 COM/2011/0112 Final; European Commission: Brussels, Belgium, 2011.
3. European Commission. *A Policy Framework for Climate and Energy in the Period from 2020 to 2030*; 22.01.2014 COM/2014/015 Final; European Commission: Brussels, Belgium, 2014.
4. Eurostat, Database on Energy. Available online: http://ec.europa.eu/eurostat/web/energy/data/main-tables (accessed on 20 December 2018).
5. Sterner, T.; Koehlin, G. Environmental Taxes in Europe. *Public Financ. Manag.* **2003**, *1*, 117–142.
6. Clemente, J. Europe's Energy and Electricity Policies Are a Bad Model. *Forbes*, 27 December 2015. Available online: https://www.forbes.com/sites/judeclemente/2015/12/27/europes-energy-and-electricity-policies-are-a-bad-model/#1bdd13623c02 (accessed on 26 March 2018).
7. Alberini, A.; Filippini, M. Response of residential electricity demand to price: The effect of measurement error. *Energy Econ.* **2011**, *33*, 889–895.
8. Ozturk, I. A literature survey on energy-growth nexus. *Energy Policy* **2010**, *8*, 340–349.
9. Bouoiyour, J.; Selmi, R.; Ozturk, I. The nexus between electricity consumption and economic growth: New insights from meta-analysis. *Int. J. Energy Econ. Policy* **2014**, *4*, 621–635.
10. Suri, V.; Chapman, D. Economic growth, trade and energy: Implications for the environmental Kuznets curve. *Ecol. Econ.* **1988**, *5*, 195–208.
11. Luzzati, T.; Orsini, M. Investigating the energy-environmental Kuznets curve. *Energy* **2009**, *34*, 291–300.
12. Pablo-Romero, M.P.; De Jesus, J. Economic growth and energy consumption: The energy-environmental Kuznets curve for Latin America and the Caribbean. *Renew. Sustain. Energy Rev.* **2016**, *60*, 1343–1350.
13. Aruga, K. *Does the Energy-Environmental Kuznets Curve Hypothesis Sustain in the Asia-Pacific Region*? MPRA Paper 80692; University Library of Munich: Munich, Germany, 2017.
14. Pablo-Romero, M.; Sanchez-Brada, A. Residential energy environmental Kuznets curve in the EU-28. *Energy* **2017**, *125*, 44–54.
15. Yin, H.; Zhou, H.; Zhu, K. Long- and short-run elasticities of residential electricity consumption in China: A partial adjustment model with panel data. *Appl. Econ.* **2016**, *48*, 2587–2599.
16. Liu, Y.; Gao, Y.; Hao, Y.; Liao, H. The relationship between residential electricity consumption and income: A piecewise linear model with panel data. *Energies* **2016**, *9*, 831.
17. Labandeira, X.; Labeaga, J.M.; Lopez-Otero, X. A meta-analysis on the price elasticity of energy demand. *Energy Policy* **2017**, *102*, 549–568.
18. Morley, B. Empirical evidence on the effectiveness of environmental taxes. *Appl. Econ. Lett.* **2012**, *19*, 1817–1820.
19. Lapinskiene, G.; Peleckis, K.; Nedelko, Z. Testing environmental Kuznets curve hypothesis: The role of enterprise's sustainability and other factors on GHG in European countries. *J. Bus. Econ. Manag.* **2017**, *18*, 54–67.
20. Baumol, W.J.; Oates, W.E. *The Theory of Environmental Taxation*, 2nd ed.; Cambridge University Press: Cambridge, MA, USA, 1988.
21. Bosquet, B. Environmental tax reform: Does it work? A survey of the empirical evidence. *Ecol. Econ.* **2000**, *34*, 19–32.
22. Stern, D.I. The rise and fall of the environmental Kuznets curve. *World Dev.* **2004**, *32*, 1419–1439.
23. Speck, S. The design of carbon and broad-based energy taxes in European countries. *Vt. J. Environ. Law* **2008**, *10*, 31–59.
24. Freiere-Gonzales, J. Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review. *J. Policy Model.* **2017**, *40*, 194–223.
25. Bye, T.; Bruvoll, A. Taxing Energy—Why and How? The Present Policies across Western Countries. Statistics Norway July 2008, Reports 2008/28. Available online: https://www.ssb.no/a/english/publikasjoner/pdf/rapp_200828_en/rapp_200828_en.pdf (accessed on 26 March 2018).

26. Markandya, A. Environmental taxation: What have we learnt in the last 30 years? In *Environmental Taxes and Fiscal Reform. Central Issues in Contemporary Economic Theory and Policy*; Castellucci, L., Markandya, A., Eds.; Palgrave Macmillan: London, UK, 2012; pp. 9–37.
27. Gago, A.; Labandeira, X.; Otero, X.L. A panorama on energy taxes and green tax reforms. *Hacienda Pública Española* **2014**, *208*, 145–190.
28. Kosonen, K.; Nicodeme, G. The Role of Fiscal Instrument in Environmental Policy. Taxation Paper 19. 2009. Available online: https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/gen_info/economic_analysis/tax_papers/taxation_paper_19.pdf (accessed on 26 March 2018).
29. De Mooij, R.A.; Parry, I.; Keen, M. (Eds.) *Fiscal Policy to Mitigate Climate Change*; International Monetary Fund: Washington, DC, USA, 2012.
30. Miller, S.J.; Vela, M.A. *Are Environmentally Related Taxes Effective*? Inter-American Development Bank Working Series: Washington, DC, USA, 2013.
31. Aigner, R. *Environmental Taxation and Redistribution Concern*; Max Planck Institute for Research on Collective Goods: Bonn, Germany, 2011.
32. The Organisation for Economic Co-Operation and Development (OECD). *The Political Economy of Environmentally Related Taxes*; OECD: Paris, France, 2006.
33. Oueslati, W.; Zippererb, V.; Rousselierec, D.; Dimitropoulosa, A. Energy taxes, reforms and income inequality: An empirical cross-country analysis. *Int. Econ.* **2017**, *150*, 80–95.
34. Grossman, G.; Krueger, A. Economic growth and the environment. *Q. J. Econ.* **1995**, *110*, 353–377.
35. Auci, S.; Trovato, G. The environmental Kuznets curve within European countries and sectors; greenhouse emission, production function and technology. *Econ. Politica* **2018**, doi:10.1007/s40888-018-0101-y.
36. Mazur, A.; Phutkaradze, Z.; Phutkaradze, J. Economic growth and environmental quality in the European Union countries–is there evidence for the environmental Kuznets curve. *Int. J. Manag. Econ.* **2015**, *45*, 108–126.
37. Kounetas, K.E. Examining the Convergence Hypothesis in Energy Consumption, CO_2 Emissions and Carbonization Index. Evidence from EU Countries. *SSRN Electron. J.* **2017**, doi:10.2139/ssrn.3058616.
38. Hertwich, E.G.; Roux, C. Greenhouse gas emissions from the consumption of electric and electronic equipment by Norwegian households. *Environ. Sci. Technol.* **2011**, *45*, 8190–8196.
39. To, W.M.; Lee, P.K.C. GHG emissions from electricity consumption: A case study of Hong Kong from 2002 to 2015 and trends to 2030. *J. Clean. Prod.* **2017**, *165*, 589–598.
40. Lechtenboehmer, S.; Schuering, A. The potential for large scale savings from insulating residential buildings in the EU. *Energy Effic.* **2009**, *4*, 257–270.
41. International Monetary Fund. *World Economic Outlook Database*; International Monetary Fund: Washington, DC, USA, October 2017.
42. Baltagi, B.H. *Econometric Analysis of Panel Data*, 4th ed.; John Wiley & Sons: Chichester, UK, 2008.
43. Roodman, D. How to do xtbond2: An introduction to difference and system GMM in Stata. *Stata J.* **2009**, *9*, 86–136.
44. Borozan, D. Regional-level household energy consumption determinants: The European perspective. *Renew. Sustain. Energy Rev.* **2018**, *90*, 347–355.
45. Ekins, P.; Speck, S. Competitiveness and exemptions from environmental taxes in Europe. *Environ. Res. Econ.* **1999**, *13*, 369–396.
46. Azevedo, I.M.L.; Morgan, M.G.; Lave, L. Residential and regional electricity consumption in the U.S. and EU: How much will higher prices reduce CO_2 emissions? *Electr. J.* **2011**, *24*, 21–29.
47. Espey, J.A.; Espey, M. Turning on the lights: A meta-analysis of residential electricity demand elasticities. *J. Agric. Appl. Econ.* **2004**, *36*, 65–81.
48. Filipovic, S.; Verbic, M.; Radovanovic, M. Determinants of energy intensity in the European Union: A panel data analysis. *Energy* **2015**, *92*, 547–555.
49. Pye, S.; Dobbins, A.; Baffert, C.; Brajkovic, J.; Grgurev, I.; de Miglio, R.; Deane, P. Energy poverty and vulnerable consumers in the energy sector across the EU: Analysis of policies and measures. *Policy Rep.* **2015**, *2*, 1–48.
50. Bertoldi, P.; Lopez Lorente, J.; Labanca, N. *Energy Consumption and Energy Efficiency Trends in the EU-28 (2000–2014)*; Joint Research Centre: Ispra, Italy, 2016.

51. Kavousian, A.; Rajagopal, R.; Fischer, M. Determinants of residential electricity consumption: Using smart meter data to examine the effect of climate, building characteristics, appliance stock, and occupants. *Energy* **2013**, *55*, 184–194.
52. Almeida, A.; Fonseca, P.; Schlomann, B.; Feilberg, N. Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations. *Energy Build.* **2011**, *43*, 1884–1894.
53. Poortinga, W.; Steg, L.; Vlek, C. Values, environmental concern and environmental behavior: A study into household energy use. *Environ. Behav.* **2004**, *36*, 70–93.
54. Gatersleben, B.; Steg, L.; Vlek, C. Measurement and determinants of environmentally significant consumer behavior. *Environ. Behav.* **2002**, *34*, 335–362.