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Electricity prices and energy intensity in Europe

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ABSTRACT

The purpose of this article is to analyse the impact of residential electricity prices on energy intensity in Europe. The research is primarily based on a panel analysis for the European Union (EU-28) member states plus Norway over the period 1990–2015, to which a fixed-effect estimator was applied. The results suggest that the residential electricity price has one-third on energy intensity, taking into account the control variables. This implies that the level and structure of electricity prices should be considered as a potential energy policy tool for improving energy efficiency by reducing energy intensity. The results also suggest that energy intensity in Europe was favourably affected by the restructuring of industrial companies in transitional economies, the implementation of national programmes for improvement of energy efficiency, and the introduction of EU Emissions Trading Scheme.

1. Introduction

Sustainable development is monitored by the European Union (EU) using different sustainability indicators, energy intensity (EI) being among the most important ones (Grzebyk and Stec, 2015). Many researchers have analysed EI as one of the drivers of economic development and energy consumption (Freeman et al., 1997; Streimikiene, 2007; Ahmed and Azam, 2016; Sweidan and Alwaked, 2016; Zhang et al., 2016; Lan-Yue et al., 2017). Energy intensity is defined in terms of the energy required from coal, electricity, oil, natural gas, and renewable sources per unit of output as typically measured by gross domestic product (GDP). As the ratio of gross inland consumption and GDP, energy intensity is represented in kilograms of oil equivalent (kgoe) per EUR 1000. If an economy uses less energy per unit of GDP, it is considered more energy efficient. In practice, however, this relationship is more complex, as energy intensity is affected, among other factors, by the structure of an economy, structural changes, technological development, climate, and many other factors (IEA, 2009).

The aim of the EU is to achieve 30% savings in primary energy consumption by 2030 (EC, 2016a,b). Enhancing energy efficiency in the residential sector was of special interest, as it presents substantial potential for cost-effective savings (Cerin et al., 2014). In the structure of end-use energy consumption, households have a 24.8% share, which has increased steadily by a total of 25% since 1990 (EC, 2016a,b). Residential electricity consumption is especially high for building heating and cooling of space and water, as well as for cooking. Electricity consumption for heating is especially high in Norway, Finland, Estonia, and the Czech Republic, with shares of about 60%. However, since 2000, there has been some improvement in most countries. Sweden, the Netherlands, and Germany reduced electricity consumption due to energy efficiency improvements, while Romania, Slovenia, Latvia, and Slovakia experienced behavioural savings linked to higher prices and lower income (EC, 2015).

The impact of residential energy policies can be observed as a reduction in energy usage in the construction industry, improved technological performance, reasonable energy consumption, and switching to renewable sources (Andrews-Speed, 2009; Haas et al., 1998; Weiss et al., 2012; Howard et al., 2006; Boardman, 2004). However, lack of information, along with technical, institutional, legal, and financial barriers, have been identified as market failures and obstacles to investment in energy efficiency. It has been found that market-based and organizational/individual behavioural factors play important roles in energy efficiency investment towards sustainable development (Lee, 2015). The crucial factors for enhancing energy efficiency can be summarised as incentives, information, initiatives, innovations, and investment (Golubchikov and Deda, 2012). The results of empirical research imply that

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financial incentives and energy performance standards have improved energy efficiency, whereas labelling and educational campaigns as informative methods have not had a significant effect on fostering efficiency (Filippini et al., 2014).

Several structural aspects should be taken into account. Liberalisation policies and competitive markets, for example, are expected to result in enhanced economic efficiency and lower electricity costs and prices. Several authors empirically demonstrated that efficiency increases and electricity cost decreases due to regulatory reforms (Akkemik and Oguz, 2011; Kunneke and Voogt, 1997). On the other hand, experiences from Slovenia (Hrovatin et al., 2009) and South East European countries (Pollitt, 2009) showed that in most cases, electricity price increases. Most of the recent research demonstrates that regulatory reforms and the subsequent increase in electricity price are two main factors that can improve energy intensity of an economy (Filipović et al., 2014, 2015b; Lin and Liu, 2013; Fisher-Vanden et al., 2004; Hang and Tu, 2007; Chai et al., 2009). Cornillie and Fankhauser (2004) found a direct correlation between energy prices and energy intensity in the transitional countries based on the arithmetic decomposition method. The results showed that two most significant drivers for using energy more efficiently are energy prices and advances in enterprise restructuring.

However, achieving efficient power pricing is easier said than done. As the cost and price of electricity service are influenced by many factors (supply and demand, import diversification, primary fuel price, severe weather conditions, network infrastructure costs, environmental protection costs, charges related to greenhouse gas emission, and excise and taxation rates), these should ideally reflected in prices in order to promote efficient use of electricity. Typically, both the end user and the producer currently base their choices on a lower energy price that does not reflect all the costs to society. Due to low price elasticity of demand in the residential sector, price is not always a solution for effecting energy intensity (Inês et al., 2011; Halvorsen and Larsen, 2011; Filippini, 2011; Blázquez et al., 2012).

This article focuses on energy intensity dynamics in Europe for the period 1990–2015. The purpose is to analyse the energy intensity in the 28 EU member states (EU-28) plus Norway, estimate the size and statistical significance of the effect that electricity price has on energy intensity, taking various control variables into account. The research is focused on the electricity price for residential consumption of 2500–5000 kWh annually, including taxes and charges (more about the methodology can be found at http://ec.europa.eu/eurostat/cache/metadata/EN/nrg_pc_204_esms.htm).

A panel-data model is employed in which the regression parameters are estimated by applying a fixed-effects estimator. The control variables are: GDP per capita, final energy consumption per capita (sum of the energy supplied to the final consumer's door for all energy uses), and dummy variables for structural characteristics and changes of individual economies and regions. In addition, to facilitate the econometric analysis, a statistical analysis is provided for a cross-section sample of 37 European countries EU-28, Norway, and eight Energy Community Treaty countries (Ukraine, Moldova, Serbia, Montenegro, FYR Macedonia, Bosnia and Herzegovina, Kosovo, and Albania) for the latest available year (2015). The Eurostat database was used as a data source due to its reliability, consistency, and relatively long time series for the analysed countries.

This article's main novelty is the econometric analysis that takes into account several control variables, thus obtaining the net effects of electricity price on energy intensity and avoiding specification biases that arise due to an incomplete model specification. The available research in this area tends to be limited in scope (Filipović et al., 2015b), due in part to data availability. This analysis contributes to the literature by covering all EU-28 plus Norway over a relatively long time period.

The article is organized as follows. Section 2 analyses the long-term evolution and structure of household's electricity price and energy intensity in Europe. The data and the research methodology are presented in Section 3. Section 4 conducts the empirical analysis, providing a broad static analysis, an econometric model, and the empirical results. Section 5 gives the main conclusions and policy recommendations, including reflections on possible limitations of the research.

2. Trends in electricity prices and energy intensity in Europe

This section starts with a presentation of structure and dynamics of electricity price for households in EU-28 plus Norway, building on the electricity market liberalisation process and on a methodology of measuring electricity price. Focus is then put on energy intensity dynamics, explaining its developments and describing the energy policy instruments and policies aimed at reducing energy intensity. The list of countries covered in the analysis is given in Table 1.

2.1. *Long-term evolution of electricity prices for households in Europe*

Since the second half of the 1990s, the EU has taken steps towards liberalisation of its electricity markets. Empirical research of effects of liberalisation and privatisation on electricity price provides mixed evidence. The findings of Fiorio and Florio (2013) suggest a linkage between public ownership and lower electricity prices for households in the EU-15 during a thirty-year period, and limited and less certain influence of liberalisation on prices. Similar research that sampled the same countries and considered the period 1995–2000 suggested that introduction of competition in electricity markets resulted in a significant downward price effects (Martin and Vansteenkiste, 2001). In some EU countries, liberalisation did not lead to an electricity market structure with less concentration and electricity prices have been found to be higher in countries with less concentrated markets (Moreno et al., 2012).

Residential electricity prices (including taxes and charges) in the EU were more or less unchanged until 2003, when they began an upward trend. The reason for their increase was the introduction of greenhouse gas emission allowances in the EU Emissions Trading Scheme (ETS) in 2005 and the greenhouse emission reduction policy promoted since 2005. Also with the aim of promotion of electricity generation from renewable energy sources, EU imposed additional charges that also increase the final electricity price. While the taxes and levies accounted for, on average, 15% of the price in kWh in 1991, their share was 32% at the end of 2011 (Cruciani, 2011). The structure of electricity price for medium residential consumption of 2500–5000 kWh annually (including taxes and charges) is shown in Fig. 1 for the second semester of 2015.

To estimate average prices in the EU, specified prices are combined with national residential consumption. The electricity price that consumers actually pay is affected by electricity tariffs and contract structures, which usually involves many factors, such as established charges and unit prices that differ in relation to the electricity consumed and period of consumption. Residential electricity bills will be impacted by costs associated with energy efficiency policies, renewable energy policies, emissions trading schemes, and investment in infrastructure. On-bill funding for policy priorities in the member states comes from either production or network charges or from taxes or levies, including the value-added tax (VAT) and other taxation instruments. The VAT is the general tax applied to every business activity involved in the

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Table 1
The list of countries covered in the analysis.

EU-28 plus Norway	Abbreviation	EU-15	Energy Community Treaty countries	Abbreviation
Austria	AT	Austria	Albania	AL
Belgium	BE	Belgium	Bosnia and Herzegovina	BA
Bulgaria	BG		FYR Macedonia	MK
Cyprus	CY		Kosovo	KS
Czech Republic	CZ		Moldova	MD
Croatia	HR		Montenegro	ME
Denmark	DK	Denmark	Serbia	RS
Estonia	EE		Ukraine	UA
Finland	FI	Finland		
France	FR	France		
Germany	DE	Germany		
Greece	EL	Greece		
Hungary	HU			
Ireland	IE	Ireland		
Italy	IT	Italy		
Latvia	LV			
Lithuania	LT			
Luxembourg	LU	Luxembourg		
Malta	MT			
Netherlands	NL	Netherlands		
Poland	PL			
Portugal	PT	Portugal		
Romania	RO			
Slovakia	SK			
Slovenia	SI			
Spain	ES	Spain		
Sweden	SE	Sweden		
United Kingdom	UK	United Kingdom		
Norway	NO			

manufacture and delivery of goods and services.

The relative share of taxes in 2015 amounted on average to 28.5%. The lowest levels were found in Malta (5%) and Lithuania (13%), while the highest levels were observed in Portugal (50%), Germany (52%), and Denmark (69%). According to the Eurostat data for the second semester of 2015, the highest electricity prices were recorded in Denmark, Germany, and Belgium, while the lowest prices were found in Bulgaria, Hungary, and Estonia. Compared to Bulgaria, the Danish electricity price was three times higher. The average electricity price in EU-28 was 21.03 eurocents per kWh. Based on a medium level of consumption, residential electricity prices in eurocents (nominal and parity) per kWh for the second half of 1990, 1995, 2000, 2005, and 2015 are presented in Table 2 (data are gathered two times a year, thus we used end-of-year data).

When applying the purchasing power parity standard, electricity price is the highest in Poland, Cyprus, and Portugal, while it is relatively inexpensive in the United Kingdom, Slovenia and Spain. Residential consumers pay the smallest tax contribution in the United Kingdom (4.7%), where relatively low taxes are added to the basic price. On the other hand, Denmark charges the highest taxes, which account for 69.5% of the bill. The current level of electricity price for medium residential consumption of 2500–5000 kWh annually, including taxes and charges and expressed in parity per kWh, is presented in Fig. 2 for the second semester of 2015.

2.2. Historical development of energy intensity in Europe

During the last two decades, the EU member states have made a significant progress in reducing the energy intensity. In the first half of the 1990s, a slowdown in the reduction of energy intensity was primarily caused by low GDP, low fossil fuel prices, and a general low tendency of the EU-15 to save energy. Generally, in this period the most important drivers of energy intensity reduction were influenced by modified economic structure that was reflected by prioritizing services over industry and industries that use less energy. In the late 1990s, the energy-efficiency improvements became more explicit. Energy intensity was improved in the newly introduced States by the modified structure of national economies and increased prices of energy. However, energy intensity in new member countries was still higher than in the EU-15.

According to Eurostat data, energy intensity in the EU-28 in 2015 was 164 kgoe/1000 EUR. Ireland and Denmark were the countries with the lowest amount of energy required to produce a unit of GDP (62 and 65 kgoe per 1000 EUR, respectively). By comparison, Bulgaria and Estonia were still the countries with the highest level of energy intensity (448 and 358 kgoe per 1000 EUR, respectively), although they recorded a significant reduction in energy intensity in the period 2000 to 2015 (−41% and −23%, respectively). Compared to 2000, all member states saw a decrease in their energy intensity, with Slovakia, Lithuania, Romania, Ireland, and Bulgaria recording decreases of more than 40% (see Fig. 3).

To promote energy efficiency, the EU member states introduced several energy policy instruments. The number of instruments and the policy mix was different from one member state to another. Out of the overall measures, legislative mandates (namely, the energy performance standards) and financial incentives (such as subsidies and tax deductions) were used the most, while informative measures (such as labelling and information, and education campaigns), were used to a lesser degree. The EU policy led to directives on energy efficiency and energy services, energy performance of buildings, labelling of electrical appliances, and eco-design for energy using products. The EU energy efficiency policies significantly influence the residential sector, as they represent about one-third of all implemented measures at the national level.

It is important to highlight the Energy Community Treaty countries (Ukraine, Moldova and the six Western Balkan countries of Albania, Bosnia and Herzegovina, FYR Macedonia, Kosovo, Montenegro, and Serbia), where energy intensity is much higher compared to the EU-28 average (594 kgoe/EUR). In 2015, the

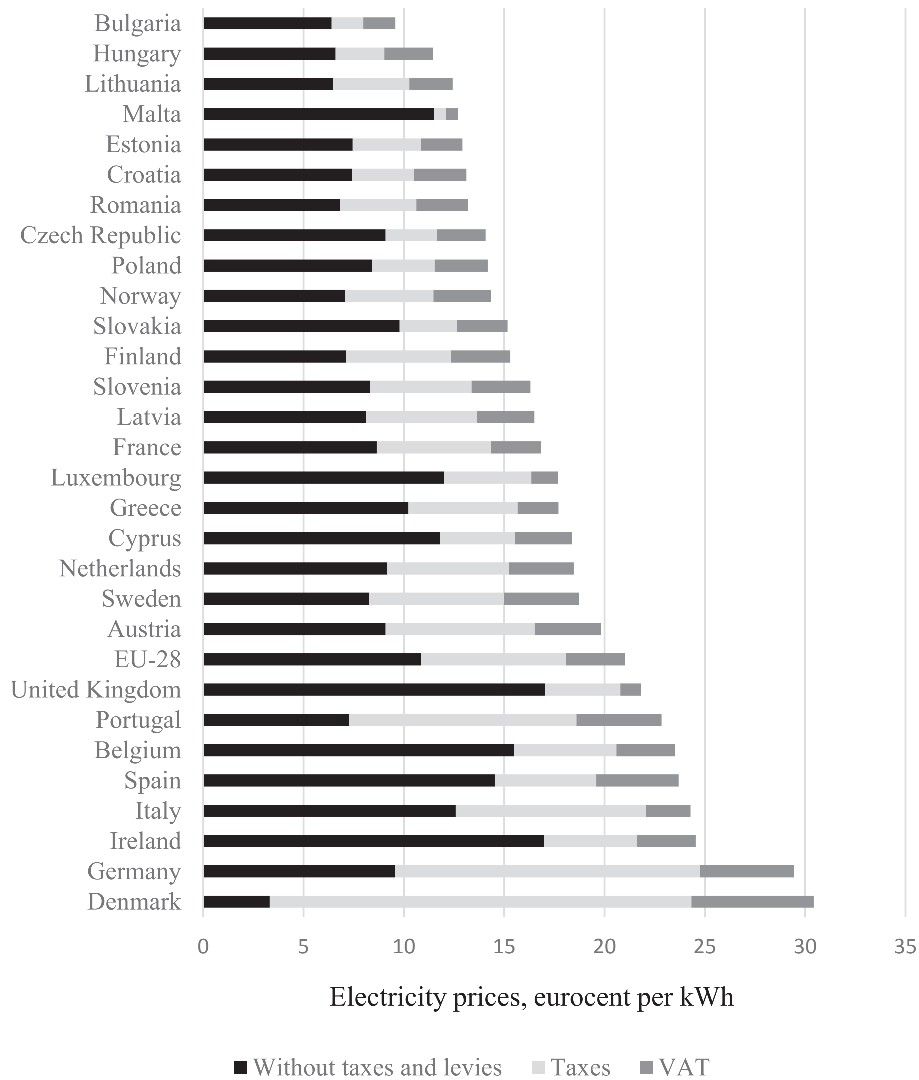

Fig. 1. Residential electricity prices in the EU-28 plus Norway in 2015, in eurocent per kWh.
Note: The data represent the second semester of 2015 for medium residential annual consumption between 2500 and 5000 kWh.
Source: Eurostat, data code nrg_pc_204.

corresponding level for the EU-28 was 164 kgoe/EUR, while energy intensity in the Energy Community Treaty countries ranged from 259 kgoe/1000 EUR in Albania to 1366 kgoe/1000 EUR in Ukraine. The Energy Community Treaty, signed in 2003, introduced systematic liberalisation of the energy sector, enabling these countries to use new tools to address, low energy tariffs and failure to comply with payment terms, both of which weaken consumer motivation toward energy efficiency. High energy intensity in the Energy Community Treaty countries can generally be explained by a broad usage of electricity for residential heating, high energy losses, and inefficiency in end usage, all of which are assumed to be associated with low electricity prices.

The Energy Community Treaty implies liberalized fuel supply, and thus each country has officially complied with the requirement to separate vertically combined electricity suppliers. However, energy prices remain relatively low and commercial consumers typically subsidize residential consumers. High levels of incurred losses (failure to pay bills and theft) are additional complications. Meanwhile, households that require help to pay for electricity must be supported by specially designed government schemes. One means of achieving these goals is tariff reform, including the introduction of block tariff design by regulatory bodies (Filipović and Tanić, 2009). Despite the fact that electricity prices are below ten eurocents per kWh, the Energy Community Treaty countries are the most affected countries by energy poverty. Besides harsh winters, these countries have also been disproportionately affected by implied energy price subsidies, dependence on polluting energy sources, interference by the state, state ownership of energy enterprises, and disorganized housing stocks and heating systems.

The Energy Community Treaty is dedicated to solving problems within social sphere, given that liberalisation and deregulation of energy can negatively influence affordable residential energy prices. The Treaty is a proactive method of handling some of the social effects of energy liberalisation in member countries. It has helped to establish social safety nets for dealing with the growth of energy prices, as well as new comprehensive measures, such progressive pricing structures (including block tariffs) under which less consumption results in a lower bill. However, measures of social support are mainly used for political purposes (Bouzarovski et al., 2012), demonstrated by the inadequateness of energy subsidies and non-payment practices.

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Table 2
Residential electricity prices in the EU-28 plus Norway in 2000, 2005, 2010, and 2015, in eurocents (nominal and parity) per kWh.

	2000		2005		2010		2015	
	Nominal	Parity	Nominal	Parity	Nominal	Parity	Nominal	Parity
Austria	13.23	12.73	13.91	13.48	19.30	17.51	19.83	18.26
Belgium	14.29	13.64	14.29	13.89	19.74	17.80	23.52	21.31
Bulgaria			6.54	18.26	8.30	18.72	9.57	20.71
Croatia			8.76	13.99	11.53	16.44	13.12	20.72
Cyprus			12.03	23.76	20.21	22.78	18.38	20.18
Czech Rep.	5.84	12.72	8.71	15.66	15.49	21.06	14.08	22.03
Denmark	19.60	15.30	23.20	17.28	27.08	19.86	30.42	22.57
Estonia			7.13	12.20	10.04	14.81	12.91	17.80
Finland	8.71	7.82	10.38	8.98	13.70	11.48	15.30	12.33
France	11.54	11.09	11.94	11.12	13.50	12.03	16.82	15.70
Germany	15.41	13.80	18.01	17.11	24.38	23.36	29.46	28.25
Greece	5.98	7.60	6.94	8.38	12.11	13.17	17.71	21.66
Hungary	6.83	14.54	11.47	18.98	15.74	26.72	11.45	20.45
Ireland	8.94	8.25	14.36	12.05	18.75	16.98	24.54	22.02
Italy	20.95	22.81	20.10	19.56	19.20	18.78	24.28	24.13
Latvia			8.29	16.71	10.48	16.04	16.50	24.45
Lithuania			7.18	14.53	12.16	20.56	12.43	20.60
Luxembourg	11.11	9.89	15.02	13.77	17.47	14.46	17.67	14.73
Malta	6.20	21.17	7.69	26.23	16.53	22.63	12.69	15.82
Netherlands	16.00	15.22	19.60	18.64	17.89	16.07	18.46	17.02
Norway	9.38	7.48	16.33	12.43	19.07	12.92	14.34	10.55
Poland	8.10	15.84	10.59	19.72	13.82	23.11	14.18	24.90
Portugal	12.56	16.98	13.80	16.43	16.66	20.12	22.85	29.32
Romania			9.47	20.34	10.52	21.56	13.19	26.49
Slovakia			13.30	25.38	16.37	24.49	15.17	22.93
Slovenia	9.88	13.91	10.49	14.59	14.26	16.97	16.31	20.40
Spain	10.91	12.93	10.97	12.09	18.51	19.70	23.70	26.47
Sweden	10.43	8.39	13.33	11.44	19.58	15.44	18.74	14.64
UK	10.72	9.29	9.26	8.64	14.49	13.54	21.83	17.04

Note: The data represent the second semester of the respective year for medium residential annual consumption between 2500 and 5000 kWh.
Source: Eurostat database, Electricity prices for domestic consumers – bi-annual data.

3. Research methods

The research problem is focused on the relationship between electricity price and energy intensity of the economy. A panel-data model for the EU-28 plus Norway, based on data for the period 1990–2015, is employed. In addition, the relationship between electricity price and energy intensity is analysed for 37 countries and the EU-28 average statically for the year 2015. Eurostat was used as the main data source, as it is considered the most reliable and consistent source of data for European countries. The data used for the analysis cover the period 1990 to 2015 for 30 entities (http://ec.europa.eu/eurostat/data/database, accessed annually during 2014–2017 and merged due to different data availability by using growth rates): EU-28, Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, and Norway.

Key variables of interest are electricity price and energy intensity for medium residential consumption. The electricity price for residential consumers relates to the average national price in Euros per kWh, which includes taxes, levies, non-tax levies, fees and VAT that can be applied for the second half of a year for a medium level of residential consumption (combination between band DC and annual consumption 2500 kWh–5000 kWh). Control variables include GDP per capita and final energy consumption per capita. GDP per capita is expressed in EUR 1000 per inhabitant, where GDP is measured at market prices. Final energy consumption per capita expresses the sum of energy supplied to final consumers by using a common energy unit (ktoe).

Energy intensity is a ratio calculated between gross inland consumption of energy and GDP and is presented in kilograms of oil equivalent (kgoe) per EUR 1000. The calculation of energy intensity used GDP as its basis, taking into account constant prices (2000 prices are chain-linked) and exchange-rate adjustments.

Each country has its own properties or individual effects so the panel-data econometric technique is adapted to current data to check for discrepancies. Data on the included variables are available for each entity, which means that there are 30 cross-sectional units for 26 years. The panel data (longitudinal or cross sectional time-series data), allows for observing the behaviour of entities over time. The panel is unbalanced, meaning that there are some missing observations; we are missing data in the pre-2000 period for some countries. As explained in the next section, the fixed effect (or the least-squares dummy variable) estimator was used to calculate the values of the parameters.

In addition, the analysis attempts to capture the structural characteristics and changes of the individual economies and EU-wide structural changes that affect the energy intensity by including additional dummy variables. Measures for three such structural characteristics and processes were used: (1) restructuring of industrial companies in transitional economies, (2) national programmes for improvement of energy efficiency in transitional countries, and (3) the introduction of EU emissions trading scheme.

Restructuring of industrial companies relates to large state-owned companies in transitional economies that were restructured after 1990. There was a collapse of heavy industry in that period, whereas the other large companies underwent the process of modernization and productivity rationalization (Filipović et al., 2015a). The number of small and medium enterprises that modernized was marginal. This phase was also characterised by economic recession and a reduction of all economic activities. In the model, this process was captured by a dummy variable $Dres = 1$ for transitional economies with the highest progress in this process, i.e.

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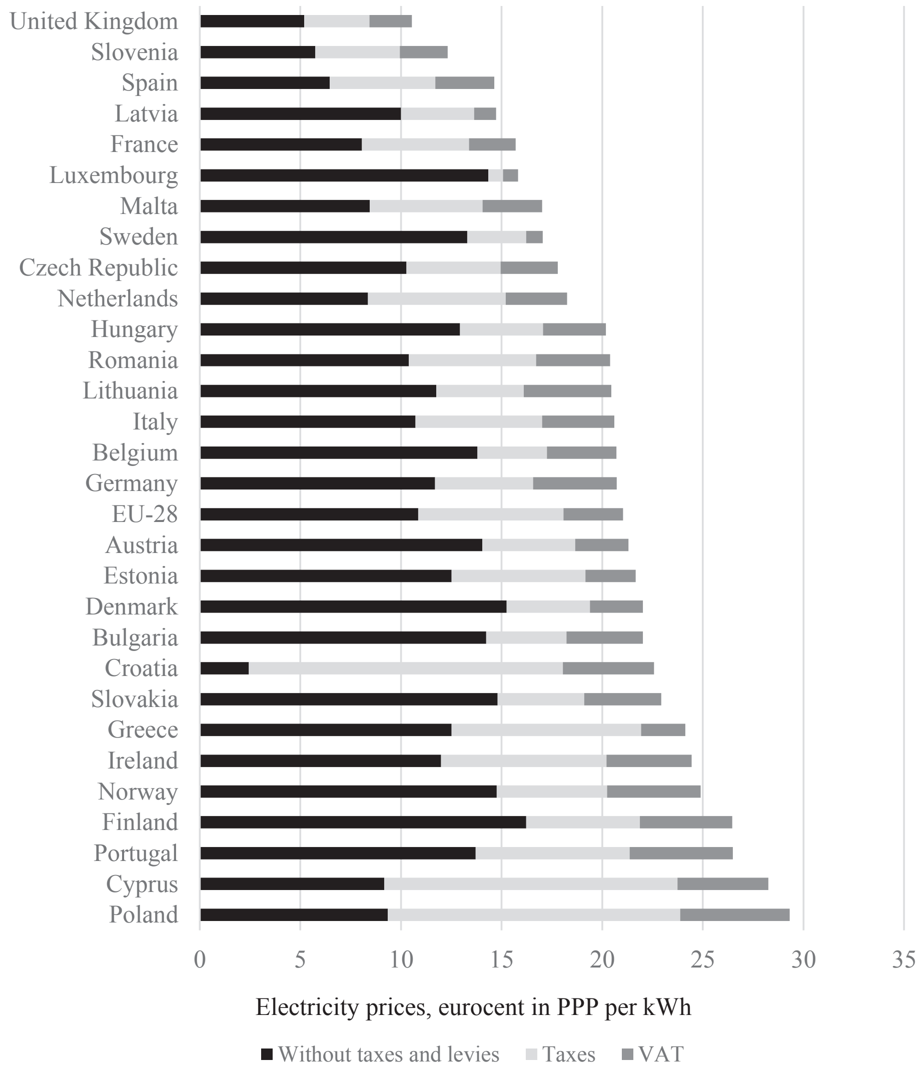

Fig. 2. Residential electricity prices in the EU-28 plus Norway in 2015, eurocent in parity per kWh.
Note: The data represent the second semester of 2015 for medium residential annual consumption between 2500 and 5000 kWh.
Source: Eurostat, data code nrg_pc_204.

the Czech Republic, Poland, Hungary, Slovakia, Estonia, Lithuania, and Latvia, during the first transition phase of 1990–1999, and 0 otherwise.

National programmes for improvement of energy efficiency in transitional countries refer to policies to decrease energy intensity in the EU-28 during the period 2002–2015 in accordance with EC (2014). During this period, the adoption of more efficient equipment and technologies, modernization of industries, thermal performance of dwellings and public buildings, and reform of electricity tariffs leading to substantial reductions in real energy intensity. The highest reduction was recorded for Slovakia (−51%), followed by Romania (−49%), Lithuania (−47%), and Ireland (−46%), which was captured in the model by a dummy variable $Dnp = 1$ for these countries during the period 2002–2015, and 0 otherwise.

The introduction of EU emissions trading scheme refers to the first and still by far the biggest international system by emissions coverage for trading greenhouse gas emission allowances that started operating in 2005 in EU member states and three countries outside of EU (Iceland, Liechtenstein, and Norway). One of the effects of the scheme was to increase the final energy price (Ellerman et al., 2010). In the model, this process was captured by a dummy variable $Dets = 1$ for all EU-28 member states and Norway since 2005 inclusive, and 0 otherwise.

4. Results and discussion

First, statistical analysis is provided for a cross-section sample of 37 European countries for the latest available year (2015). Then, the panel-data analysis is employed to examine the relationship between energy intensity and electricity price for medium residential consumption for the EU-28 plus Norway over the 1990–2015 period.

4.1. Static analysis of electricity price and energy intensity in Europe

This section reports a static analysis of the relationship between electricity prices and the energy intensity of the economies for the EU-28, Norway, and eight Energy Community Treaty countries (Albania, Bosnia and Herzegovina, FYR Macedonia, Kosovo, Montenegro, Moldova, Serbia, and Ukraine). A total of 37 countries are observed for the year 2015. The goal was to see how the energy

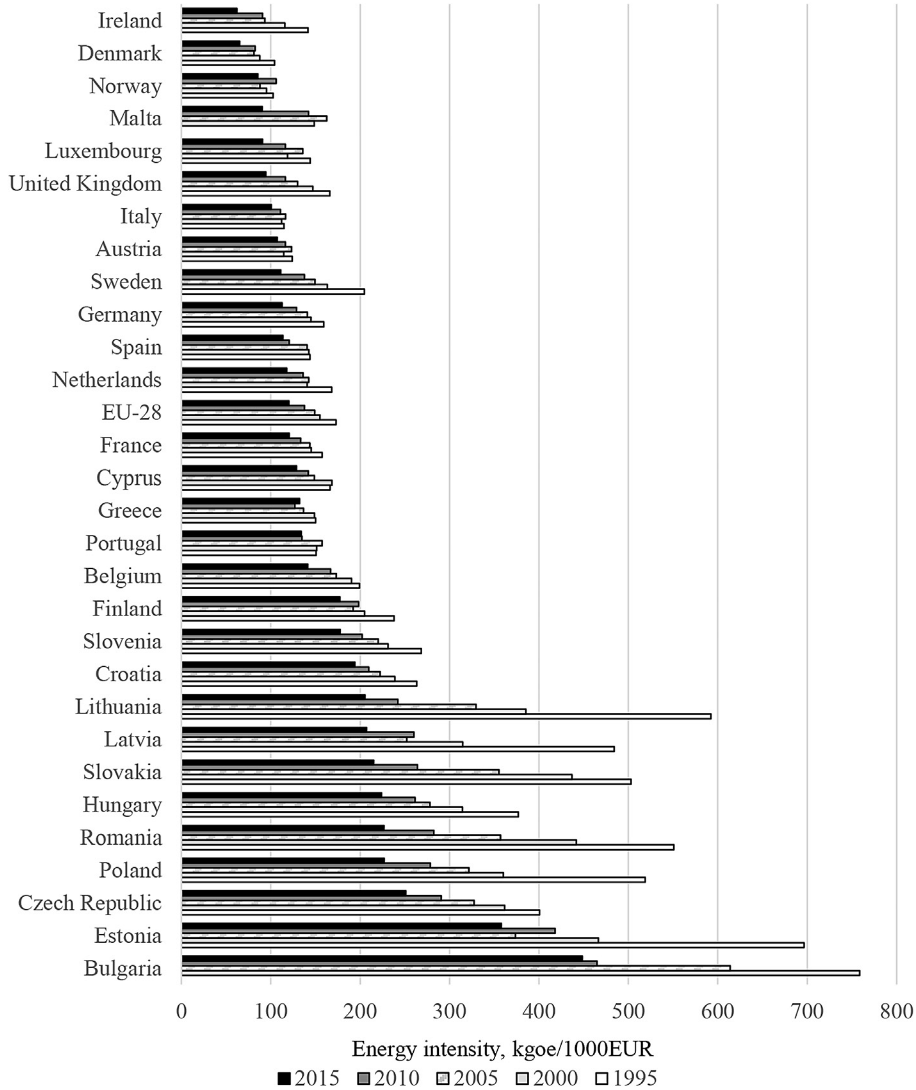

Fig. 3. Energy intensity in 1995, 2000, 2005, 2010 and 2015 for the EU-28 plus Norway, in kgoe/1000 EUR.
Source: Eurostat, data code tsdec360.

intensity of the economy (in kgoe/1000 EUR) correlates to the electricity price for households (in EUR/kWh). The electricity price for residential consumers described in this section include taxes, levies, non-tax levies, fees, and VAT, as such a combination usually expresses the bill amount charged to residential users. Data on energy intensity of the economy were derived from available statistical databases for given countries. The data are presented in Table 3. A scatterplot also shows the relationship between electricity price and energy intensity (Fig. 4).

The results presented in Table 3 and Fig. 4 show relatively high correlation between energy intensity and electricity price for residential consumers in observed countries (the correlation coefficient was −0.59 with a p−level of 0.001). The lowest electricity prices were observed for Kosovo, Ukraine, and Serbia. In Energy Community Treaty countries, prices ranged from 6.14 (Kosovo) to 9.88 eurocents per kWh (Montenegro). In EU-28 countries, Bulgaria had the lowest price, while the highest price was in Denmark and Germany.

The average value of energy intensity of the economy in the EU-28 region plus Norway was 164 kgoe/1000 EUR, and 594 kgoe/1000 EUR in the remaining eight countries of Energy Community. In all countries with high electricity prices, a low level of energy intensity was recorded. Relative to GDP, the least energy is spent in countries where electricity is most expensive (Denmark and Germany). At lower electricity prices, energy intensity of the economy is higher, though not always proportionally to energy intensity, as electricity consumption is affected by the consumption of other energy generating products as well. However, all countries with a low cost of electricity recorded a high level of energy intensity. The country that consumed the most energy per unit of GDP was Ukraine. Apart from Ukraine, high energy intensity values were recorded in other countries with low electricity prices, including Moldova, Bosnia and Herzegovina, Serbia, and Bulgaria. Estonia, Czech Republic and Romania were marked by high energy consumption per unit of GDP, compared to the average energy intensity of the observed sample.

The results of the static analysis show a clear discrepancy in energy intensity among the EU member states and the Energy Community Treaty countries. In the Energy Community Treaty countries, unrealistically low electricity prices appear to account for irrational usage. Given the economic crisis and reduced economic activity, the level of energy intensity in these countries is still high.

Table 3
Energy intensity and electricity prices in eurocents per kWh for residential consumers in Europe in 2015.

EU-28 plus Norway		EI	EP	Energy Community Treaty countries		EI	EP
Austria	AT	107.1	20.34	Albania	AL	259.0	8.20
Belgium	BE	141.3	25.44	Bosnia and Herz.	BA	522.0	8.30
Bulgaria	BG	448.5	9.56	FYR Macedonia	MK	336.3	8.35
Croatia	HR	194.1	13.10	Kosovo	KS	490.4	6.14
Cyprus	CY	128.7	15.27	Montenegro	ME	301.1	9.88
Czech Republic	CZ	251.0	14.20	Moldova	MD	990.1	8.81
Denmark	DK	65.1	30.88	Serbia	RS	486.1	6.45
Estonia	EE	358.0	12.08	Ukraine	UA	1365.8	6.30
Finland	FI	177.2	15.10				
France	FR	120.7	16.85				
Germany	DE	112.6	29.69				
Greece	EL	132.2	17.60				
Hungary	HU	224.0	11.14				
Ireland	IE	62.0	23.06				
Italy	IT	100.5	24.13				
Latvia	LV	207.1	16.80				
Lithuania	LT	205.4	12.37				
Luxembourg	LU	90.7	17.98				
Malta	MT	90.3	12.57				
Netherlands	NL	118.0	16.20				
Norway	NO	85.5	15.70				
Poland	PL	227.1	13.32				
Portugal	PT	133.9	23.50				
Romania	RO	226.7	12.63				
Slovakia	SK	215.1	14.23				
Slovenia	SI	177.6	16.18				
Spain	ES	113.7	21.85				
Sweden	SE	111.3	19.84				
United Kingdom	UK	94.3	19.51				

Source: Eurostat, IEA and World Bank databases; own calculations.

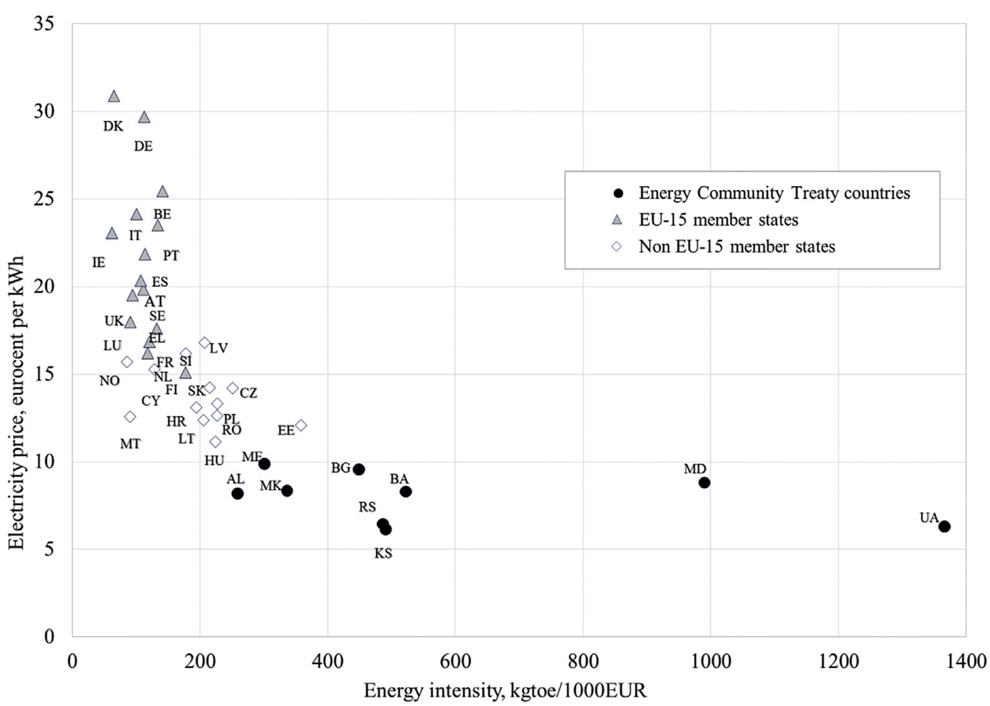

Fig. 4. Energy intensity and electricity prices for residential consumers in Europe in 2015.
Source: Eurostat, IEA and World Bank databases; own calculations.

Electricity usage is particularly high in the household sector for heating due in the absence of developed infrastructure to improve efficiency (such district heating). As energy efficiency policy is still being developed, a high level of energy intensity is expected to persevere. Relatively efficiency was found for Belgium, Italy, Portugal, and Ireland, that is, countries where the GDP is predominantly formed by activities and services with low energy intensity.

Some specific results can also be highlighted. First, although electricity in Germany is about twice as expensive as in France, Germany has negligibly lower energy intensity. French electricity production is based on nuclear power (associated with relatively stable prices), while Germany is increasingly reliant on renewable sources (associated with more volatile prices). Comparing electricity prices without taxes and other levies (see Fig. 1), the price in Germany (9.14 eurocents per kWh) is quite similar the price in France (8.39 eurocents per kWh), but the share of taxes in Germany is 53.3%, while the share in France is 35.5%. In the Energy Community Treaty countries, with an average electricity price of 8.2 eurocents per kWh, Albania has the lowest level of energy consumption per unit of GDP (259 kgoe/1000 EUR), which is close to the energy intensity of Poland and Romania. The specifics of GDP in Albania (for example, its high reliance on tourism revenues) appear to contribute to the lower values of energy intensity recorded for this country.

4.2. Panel data analysis of energy intensity in the EU-28 plus Norway

In this section, the relationship between electricity price and energy intensity was determined for the EU-28 plus Norway, accounting for GDP per capita, Final energy consumption per capita, and using structural dummy variables *Dres*, *Dnp*, and *Dets* as control variables. The empirical analysis is based on Eurostat data for the period 1990–2015.

Pooled regression is not applicable for this research, as the least squares estimator is inconsistent due to individual country effects. Bearing this in mind, the fixed-effects estimator and the random-effects estimator can be used in this case. The Hausman test rejected the null hypothesis under which the random-effects estimator is consistent (the Hausman test statistic was statistically significant in both model specifications, with p–values below 0.05); thus, only the fixed-effects estimator is consistent in this case, although not necessarily efficient. Application of the least-squares dummy variable version of the fixed-effects estimator provides a model where the intercept will vary for each entity, while the slope coefficients will be constant across entities.

Modelling the fixed effects by using the least squares dummy variable estimator gives the following model specification:

$$EI_{it}=\alpha_1+\alpha_2D_{2i}+\alpha_3D_{3i}+\ldots+\alpha_{28}D_{29i}+\beta_1EP_{it}+\beta_2GDP_{it}+\beta_3FEC_{it}+ +\beta_4Dres+\beta_5Dnp+\beta_6Dets+u_{it},\ i=1,\ldots,30,\ t=1,\ldots,26, \tag{1}$$

with $D_{2i}=1$ if the observation belongs to Austria, otherwise it is 0; $D_{3i}=1$, if the observation belongs to Belgium, otherwise it is 0; etc. Since there are 30 entities, 29 dummy variables are used to avoid the so-called "dummy variable trap." This means that there is no dummy for EU-28, as α_1 represents the intercept for EU-28 plus Norway and α_2, α_3, …, α_{29} are the differential intercept coefficients that show us how much the intercepts of Austria, Belgium, and so on differ from the intercept for EU-28 plus Norway. Parameters β_1, …, β_6 represent the regression coefficients of explanatory variables, and the disturbance term is distributed as $u_{it}\sim(0,\Sigma)$.

The assumption of homoscedasticity was tested by the modified Wald test for group wise heteroscedasticity, which did not reject the null hypothesis. The assumption of no autocorrelation was tested by the Cumby-Huizinga test for autocorrelation. As the null hypothesis of no autocorrelation was rejected at several lag orders, the heteroscedasticity and autocorrelation consistent (HAC) estimator of variance was applied to calculate the standard errors of the regression coefficients. Two specifications of model (1) were estimated. As both energy consumption and GDP in principle define the energy intensity, the effects of these two explanatory variables on energy intensity were measured separately in distinct model specifications, to avoid forcing a nonlinear relation to fit a linear relationship. Table 4 shows the estimates of regression coefficients from model (1).

It can be observed from Table 4 that residential electricity price has a statistically significant negative effect on energy intensity. Specifically, for every 1 cent/kWh increase in residential electricity price, energy intensity on average decreases in the EU-28 plus Norway by 3.67–4.92 kgoe/1000EUR. For context, in 2015 the average energy intensity in the EU-28 was 163 kgoe/1000 EUR and the average household electricity price was 17.6 cents per kWh.

Final energy consumption per capita is included in the model as a control variable, as it is a part of the data generating process of energy intensity. It has an expected positive and statistically significant effect on energy intensity. If final energy consumption per capita at current prices increases by 1000 toe per inhabitant, energy intensity on average increases in the EU-28 plus Norway by 0.066 kgoe/1000EUR. This result is in line with a finding in a World Bank (2013) study that in the most developed economies, there is a positive correlation between final energy consumption per capita and energy intensity.

GDP per capita is also considered as a part of the data generating process of energy intensity, and as such included in the empirical model. It has an expected negative and statistically significant effect on energy intensity. If GDP per capita at current prices increases by EUR 1000 per inhabitant, energy intensity on average decreases in the EU-28 plus Norway by 1.06 kgoe/1000EUR. This result is in accordance with Jimenez and Mercado (2014) and confirms that income reflects the level of economic development, which is closely related to energy efficiency improvements.

The country-specific conditional mean of energy intensity is estimated by adding a dummy variable for each country. The estimated regression coefficients for some countries were not statistically significant, meaning that energy intensity in these countries is not statistically significantly different from the conditional 1992–2015 mean of the EU-28 plus Norway (see Table 4). The conditional mean of energy intensity for the EU-28 plus Norway was 266.81–281.95 kgoe/1000EUR. The regression coefficients of the remaining dummy variables were statistically significant and demonstrate the deviation in energy intensity of a particular country from the 1992–2015 conditional mean of the EU-28 (and Norway). Countries with a negative dummy variable regression coefficient thus had a lower conditional mean of energy intensity, while countries with a positive dummy variable regression coefficient had a higher conditional mean of energy intensity than the EU-28 plus Norway average. These deviations are in accordance with the official statistics presented in Fig. 3, where energy intensity in the EU-28 member states is shown for 2000 and 2015.

The structural dummy variables also exhibit statistically significant effects on EI. As can be seen from Table 4, energy intensity was on average 186.44 kgoe/1000EUR higher in transitional economies with the greatest progress in restructuring of industrial companies (namely, the Czech Republic, Poland, Hungary, Slovakia, Estonia, Lithuania and Latvia) during the first transition phase (1990–1999) compared to the other EU-28 plus Norway during the remaining time period. The restructuring of industrial companies in these countries is associated with decreases in recorded energy intensity (that is, improved energy efficiency).

Moreover, energy intensity in countries with the most successfully implemented national programmes for improvement of energy efficiency in accordance with EC (2014), namely, Slovakia. Lithuania, Bulgaria and Estonia, was on average 380.49 kgoe/1000EUR lower during the period 2002–2015, compared to the other EU-28 plus Norway during the remaining period. This

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Table 4
Estimation of the panel data model on energy intensity, EU-28 plus Norway, 1990–2015.

Energy intensity	Specification 1			Specification 2		
	Coefficient		HAC Std. Err.	Coefficient		HAC Std. Err.
Electricity price	−367.36	***	50.64	−491.67	***	73.51
GDP p.c.	−1.0602	***	0.3167			
Final energy consumption p.c.				0.0661	***	0.013
Restructuring of industry	186.44	***	33.24			
National energy programmes				−380.49	***	35.49
Introduction of EU ETS	−15.1140	***	7.4506	−17.1278	***	5.2065
Austria	−26.75	***	4.72	−31.22	***	5.56
Belgium	60.06	***	4.89	57.64	***	5.33
Bulgaria	698.84	***	31.66	1233.69	***	45.18
Croatia	99.10	***	9.62	102.61	***	9.78
Cyprus	32.44	***	3.99	33.47	***	5.50
Czech Republic	367.29	***	14.86	363.78	***	14.28
Denmark	−26.99	***	7.23	−24.35	***	8.54
Estonia	406.66	***	13.16	846.42	***	40.43
Finland	59.84	***	4.49	51.43	***	5.81
France	−8.91	***	3.06	−14.79	**	4.19
Germany	4.02		4.43	5.98		5.67
Greece	25.84	***	4.12	−34.32	***	5.91
Hungary	216.70	***	9.09	274.28	***	20.34
Ireland	−50.77	***	5.08	−57.43	***	6.43
Italy	−13.38	***	4.34	−7.87		5.54
Latvia	127.19	***	8.37	124.57	***	8.81
Lithuania	191.52	***	20.79	625.00	***	37.60
Luxembourg	41.59	**	16.96	27.49		18.38
Malta	−6.09		6.57	−11.30		7.30
Netherlands	14.32	***	4.19	10.40	**	5.14
Poland	192.55	***	12.43	190.73	***	12.15
Portugal	2.56		3.87	3.36		4.83
Romania	382.10	***	25.48	381.18	***	25.26
Slovenia	87.33	***	5.31	83.10	***	5.54
Slovakia	349.07	***	24.09	769.42	***	44.99
Spain	−5.21	*	2.82	−7.63	*	3.91
Sweden	3.20		5.22	−1.99		6.22
United Kingdom	−55.56	***	3.84	−62.85	***	5.06
Norway	−12.31		12.42	−24.58	*	13.61
Intercept (EU-28 plus Norway)	266.81	***	7.45	281.95	***	10.07
Number of observations	583			599		
Number of groups	30			30		
F−statistic	303.08			273.67		
p−value	0.000			0.000		
log *L*	−2864			−2936		
Hausman test statistic	38.02			9.00		
p−value	0.000			0.029		

Note: Asterisks *, ** and *** denote statistical significance below the 0.1, 0.05 and 0.01 probability levels, respectively.
Source: Own calculations.

decrease in energy intensity could be attributed to the adoption of more efficient equipment and technologies, modernization of industries, and thermal performance of dwellings and public buildings, as well as reform of electricity tariffs.

Furthermore, according to the results in Table 4, the introduction of EU emissions trading scheme decreased the energy intensity in the EU-28 plus Norway on average by 15.11–17.13 kgoe/1000EUR, compared to the pre-2005 period. Though the introduction of a system for trading greenhouse gas emission allowances is expected to affect energy intensity and related variables, care should be taken when interpreting these results as they are based on relatively rough discrete measures and other factors not explicitly modelled here and would affect the results.

5. Concluding remarks

The research first provides a static statistical analysis for the year 2015, utilizing data from a cross-section sample of 37 European countries. Then it employs a panel-data analysis to examine the relationship between energy intensity and residential electricity price for the EU-28 plus Norway for the 1990–2015 time period, including GDP per capita, final energy consumption per capita, and structural dummy variables as controls.

The static analysis of energy intensity in 2015 for the EU-28, Norway, and the Energy Community Treaty countries revealed a relatively high correlation between electricity prices and energy intensity. In all countries with low electricity prices, likely due to effect of subsidies, high energy consumption per unit of GDP was observed. Low electricity prices and very high energy intensity were found in Energy Community Treaty countries (namely, Ukraine, Moldova, and Bosnia and Herzegovina). Furthermore, the highest electricity prices and the lowest energy intensity were observed for Denmark, Germany, and Belgium. The analysis also showed that countries with a developed environmental policy have a high share of taxes in the residential electricity price, which significantly increases the price and these countries also have low energy intensity. These findings have policy implications regarding the role of price in further enhancing energy efficiency in the EU.

The panel-data analysis confirmed that the residential electricity price appears to exhibit a significant negative effect on

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energy intensity in the EU-28 plus Norway, whereas GDP per capita and final energy consumption per capita exhibit negative and positive effects, respectively. The structural dummy variables also revealed statistically significant effects on energy intensity. Energy intensity was relatively: (1) higher in transitional economies with the greatest progress in restructuring of industrial companies during the first transition phase, (2) lower in countries with the most successfully implemented national energy efficiency programmes during the analysed period, and (3) lower after the introduction of the EU emissions trading scheme in 2005, compared to other analysed countries in the remaining time period.

The analysis has certain limitations that should be taken into account, indicating the direction of future research. In terms of methodology, expressing energy intensity takes into account all energy generating products contributing to GDP unit and electricity is only one of the energy generating products. In addition, the energy intensity of an economy is largely affected a country's economic structure and conditions, as well as policies. A reduction in energy intensity may reflect the impact of an economic slowdown in terms of reduced industrial activity or the impact of energy efficiency programmes.

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