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Electricity Markets during the Liberalization: The Case of a European Union Country

Štefan Bojnec * and Alan Križaj

Faculty of Management, University of Primorska, Izolska vrata 2, SI-6101 Koper-Capodistria, Slovenia; Alan.Krizaj@gmail.com

* Correspondence: stefan.bojnec@fm-kp.si or stefan.bojnec@siol.net

Abstract: This paper analyzes electricity markets in Slovenia during the specific period of market deregulation and price liberalization. The drivers of electricity prices and electricity consumption are investigated. The Slovenian electricity markets are analyzed in relation with the European Energy Exchange (EEX) market. Associations between electricity prices on the one hand, and primary energy prices, variation in air temperature, daily maximum electricity power, and cross-border grid prices on the other hand, are analyzed separately for industrial and household consumers. Monthly data are used in a regression analysis during the period of Slovenia's electricity market deregulation and price liberalization. Empirical results show that electricity prices achieved in the EEX market were significantly associated with primary energy prices. In Slovenia, the prices for daily maximum electricity power were significantly associated with electricity prices achieved on the EEX market. The increases in electricity prices for households, however, cannot be explained with developments in electricity prices on the EEX market. As the period analyzed is the stage of market deregulation and price liberalization, this can have important policy implications for the countries that still have regulated and monopolized electricity markets. Opening the electricity markets is expected to increase competition and reduce pressures for electricity price increases. However, the experiences and lessons learned among the countries following market deregulation and price liberalization are mixed. For industry, electricity prices affect cost competitiveness, while for households, electricity prices, through expenses, affect their welfare. A competitive and efficient electricity market should balance between suppliers' and consumers' market interests. With greening the energy markets and the development of the CO_2 emission trading market, it is also important to encourage use of renewable energy sources.

Keywords: electricity market liberalization; electricity prices; electricity consumption; electricity market operation; industry; households; decision support systems; Slovenia; European Union; European Energy Exchange

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1. Introduction

The electricity markets in developed and developing countries have undergone substantial reforms that have been induced by market deregulation and price liberalization [1–5], with an aim to become more competitive and efficient [6–10]. Electricity is one of the key goods in consumers' daily needs, and as such, is at the core of economy cost efficiency and household welfare [11,12]. It is one of the most important factors of production and consumption. As such, it affects industrial cost competitiveness and expenses of households [13,14]. This explains, for example, why the European Union (EU) member states aim to develop a competitive and efficient electricity market [15–17]. Such a market also allows the development of the CO_2 emission trading market, thus encouraging the use of renewable energy sources, and contributing to greenhouse gas emission reduction, which is important in the fight against climate change [18–23]. The EU, as well as most other countries in the world, aims to increase its final energy consumption with renewable energy sources [24–26].

The development of the EU internal market in electricity has sped up liberalization in this sector [27,28]. Therefore, the rationale for this study is to contribute an empirical country case study on the process of electricity market deregulation and price liberalization from previously traditionally monopolistic and government-controlled energy markets to the introduction of competitive and more efficient markets. In the EU member states, as well as many other countries in the world, the electricity markets are no longer under government control and electricity as a special commodity is traded under supply and demand market conditions and using different rules, such as spot and derivative contracts [29–32]. Our focus is on electricity prices and electricity demand by consumption in industry and households [33–35].

Experiences show the possible benefits that may result from the internal market in electricity, in terms of efficiency gains, price reductions, higher standards of service and increased competitiveness [36–39]. This article focuses on Slovenia, which has been one of the EU member states since 2004. During gradual market deregulation and price liberalization in the electricity sector, Slovenian consumers have benefited from more choice among suppliers and more competitiveness, which has improved service and energy security [40,41].

The article provides an extensive overview of the relevant literature on the drivers of electricity prices and electricity demand during market deregulation and price liberalization. More specifically, it contributes an in-depth analysis of electricity consumption by industry and households and electricity prices in Slovenia in relation to the European Energy Exchange (EEX) market during the Slovenian electricity market deregulation and price liberalization. The deregulation and liberalization of the electricity market in Slovenia began in 2001 with the segment of industrial customers with a connected power of over 41 kW. The consumption of electricity for this segment of customers represented a 65% openness of the electricity market. The next step in the electricity market liberalization took place in 2004, when all industrial customers were free to choose their electricity supplier on the market and the level of market openness in Slovenia reached 77%. Only since 2007 has a complete electricity market liberalization in Slovenia been implemented, when household customers were also free to choose their electricity supplier.

The study applied regression analysis to explore the drivers of electricity price and consumption by industry and households in Slovenia. Based on these results and research findings, it derives implications of broader relevance for Slovenia, and the EU and emerging market economies, which can be of interest to researchers and practitioners in the fields of the electricity market, energy policy and sustainable development of electricity markets.

The rest of the article is structured as follows. The second section discusses the background on the deregulation and liberalization of the electricity market. The third section presents materials and methods. The fourth section presents the empirical results. The fifth section discusses the results and derives implications. The final section concludes the findings.

2. Deregulation and Liberalization of the Electricity Market

The deregulation and liberalization of the electricity market has been the main EU priority in the field of energy policy since the late 1980s [16]. This has economic motives, given that closed national energy markets were incompatible with the concept of a single and competitive economic area. The main reason for sector deregulation was the desire to increase the efficiency of energy undertakings and the energy system as such, as well as to achieve the expected supply-side effects, i.e., lower electricity prices for final consumers [42,43]. The deregulation and liberalization of the electricity market contributed to unleashing entrepreneurial potential in the energy sector. Possibilities were explored for offering the lowest possible retail electricity prices, and, in the same way, for achieving competitive advantages, which positively affected a range of associated activities, including renewable electricity production, and encouraged completion of the market for energy derivatives [44,45].

Market participants at electricity markets were better equipped to adjust promptly to rapid economic and environmental changes and to cope with climate changes. In some countries, the deregulation and liberalization process was faster than planned in national legislation [46]. In the conditions of a high degree of transparency and a relatively low initial competitiveness, one of the objectives of market deregulation and price liberalization was achieved, that is, to reduce prices while maintaining unchanged standards of service. However, electricity prices have since increased. The process of developing competitive electricity markets was far from complete [47,48]. In practice, far too many of the EU's citizens and businesses lacked a real choice of electricity supplier. Market fragmentation along national borders, a high degree of vertical integration and high market concentration were at the root of the lack of a truly internal electricity market [49,50].

With the liberalization and opening of the electricity market, electricity became a free-traded commodity. Slovenia's electricity market has been fully opened since mid-2007, which means that all consumers are now free to choose their electricity supplier. The opening had three phases in Slovenia [51]. In the first phase, the Energy Act, which came into force in 1999 and implemented the first Electricity Directive, provided that, starting on 15 April 2001, eligible consumers should be free to choose their electricity supplier. Eligible consumers were defined as those with an installed capacity of more than 41 kW at a single point of supply. Altogether, they consumed seven billion kilowatt hours annually, which at that time meant that the percent of electricity market liberalization was 65% [51]. They were free to negotiate with their supplier for the price and quantity of electricity bought. In the second phase, Slovenia complied with the requirement that EU member states should, by 2004, open their electricity markets for all consumers other than households. In the third phase, the Energy Act, which implemented the second Electricity Directive, laid out that, starting on 1 July 2007, the electricity market should become fully opened, meaning that households should also become eligible consumers free to choose their supplier.

We set the following hypotheses (H) that are empirically tested using a regression analysis based on a monthly time-series data:

Hypothesis 1 (H1). *Electricity prices on the EEX market are significantly related to prices of primary energy sources, CO_2 emission coupon prices and variations in air temperature.*

These explanatory variables have also been specified in electricity price functions in previous studies: the prices of primary energy sources with calculations of electricity price cost elasticities [40,41,52–54], CO_2 emission coupon prices [24,55–57] and variations in local air temperature [58–60].

Hypothesis 2 (H2). *Electricity prices in Slovenia are significantly related to prices of primary energy sources, CO_2 emission coupon prices, peak electricity consumption, variations in temperature and cross-border grid transmission prices.*

The set H2 is tested separately for electricity prices in industry (H2a) and for electricity prices for households (H2b). Peak electricity consumption for industry is proxied by the industrial production index for industry economic activity [41,61]. Electricity demand and electricity prices for households can be driven by monthly gross salary as a variable for income elasticity [40,62–64].

Hypothesis (H3). *Electricity consumption in Slovenia is significantly related to prices of primary energy sources, CO_2 emission coupon prices, peak electricity consumption, and variations in air temperature.*

The set H3 is tested separately for electricity consumption in industry (H3a) and for electricity consumption in households (H3b). Peak electricity consumption for industry is proxied by daily maximum electricity power [65–67] and the industrial production index. Electricity consumption in households can be also driven by daily maximum electricity

power, cross-border transmission grid prices, monthly gross salary and gross domestic product as a macro-economic variable of the economic cycle [68–72].

Hypothesis 4 (H4). *With electricity market liberalization and increased competition in the Slovenian electricity markets, real prices were expected to decline.*

The set H4 is tested separately for electricity prices in industry (H4a) and for electricity prices in households (H4b). Electricity prices for industry can also be driven by electricity consumption in industry [41]. Electricity prices for households can also be driven by electricity consumption in households, daily maximum electricity power, cross-border transmission grid prices and monthly gross salary.

A few studies have investigated the effects of electricity market deregulation and liberalization of electricity markets on electricity prices, with mixed results between the initial price decline and later increases [1–10,25–42,73–76].

Hypothesis (H5). *Electricity consumption in Slovenia is significantly related to the price of electricity on the EEX market.*

The set H5 is tested separately for electricity consumption by Slovenian industry (H5a) and for households (H5b).

The formation of the integrated single European energy market is one of the objectives of energy and electricity policies [77–79].

3. Materials and Methods

3.1. Drivers of Electricity Prices and Electricity Consumption

Among drivers influencing electricity prices, the global fuel market, which directly affects the global energy market, and consequently the European energy market, is undergoing a transitional period [80,81]. New sources are entering the market and production facilities using fossil fuels (oil and coal) are closing down, making way for electricity producers using renewable energy sources (such as wind, sun, biomass and water) [82–85]. In particular, the trend of energy efficiency and renewable energy is characteristic of an energy-intensive industry which tries to minimize the use of fossil fuels and improve energy efficiency [86]. In the EU, procedures have been introduced to liberalize the energy market, introducing competition and free choice of energy suppliers, not just of the same energy but also between different forms of energy. These changes have had a great effect on prices, where for the United Kingdom, between 1995 and 2002, electricity prices fell by 27% in real terms for residential use and industrial consumers had to pay 38% less over the same period [24].

Europe is generally considered to be the region of the global economy where the introduction and implementation of electricity liberalization has been the most successful, with steady progress [87]. The rise in coal, oil and—linked to oil—gas prices has also considerably impacted electricity prices [88,89]. Coal, oil and gas account for approximately half of the European power generation mix and these fuel costs have experienced substantial oscillations [90]. An important factor affecting energy prices in regional markets is global energy production and global energy demand and use with overall implications on prices, revenues, and expenditures in the economies [91–93]. Large European electricity producers can affect demand and supply in individual regional markets, through their production portfolios and their own production costs, thus affecting electricity prices [94]. Another important factor affecting electricity prices is the level of integration of regional markets based on cross-border grid connections which allow the cross-border exchange of electricity among regional markets where prices are lower or higher than elsewhere [95–97]. The objective of the integration of Europe's regional electricity markets will be achieved when energy grid connections allow the unification of prices in the entire EU. This, however, is not happening for several reasons, one of them being, for example, the different tax rates for electricity in the EU member states.

Several factors affecting electricity demand and supply have been investigated in the literature [40,98–103]:

Delivery time: During work times for industry and other business activities, electricity consumption is much higher than in the evening and at night or during weekends, for which reason, higher electricity prices apply to such peak electricity consumption periods [104,105]. Some energy savings can be achieved with energy-efficient equipment and technologies [106,107].

Weather conditions with variations in air temperature and humidity: In the studied EU country, there are variations in air temperature more relevant than humidity. In countries with a large number of hydro power plants, such as Norway and Canada, rainfall is an important factor affecting electricity prices given that it increases the flow of rivers, and thus electricity production. Increased electricity production, in turn, reduces electricity prices. An increasingly important factor is wind, as the number of wind power plants has increased significantly in the past years, for example, in Denmark. In addition to rainfall and wind, electricity prices are also affected by variations in air temperature, as electricity consumption increases significantly on very cold winter days and on very hot summer days when consumers use heating or air conditioning devices [108]. Such increased consumption and its oscillations significantly affect electricity prices [109].

Prices of energy sources used for electricity production: Coal, gas and oil are energy sources used by the majority of thermal power plants, also representing their major production cost. This explains the great impact that the prices of these primary energy sources have on electricity prices, particularly in those countries where thermal power plants account for a large share of electricity production.

Electricity transmission networks: If electricity transmission capacity is reduced because of network failures or maintenance, this can increase electricity prices when demand is high, and import is not possible [110].

Economic developments: During economic expansion, electricity prices grow as increased economic activity increases the demand for electricity. The opposite happens during economic downturns, when electricity prices fall as reduced economic activity reduces demand for electricity. These price volatilities can create instabilities in cost structures and difficulties in their adjustments to price for large electricity consumers [111].

Exchange rate developments: The prices of primary energy sources are mainly expressed in US dollars, for which reason any change in the US dollar exchange rate causes changes in prices of primary energy sources, and thus in electricity production costs.

Nuclear-, thermal- and water-power plants: Failures or repairs of electricity power plants significantly reduce electricity supply and, if demand is high, increase electricity prices.

Continuous increase in consumption: Electricity consumption has been growing faster than electricity production capacity, which in turn has created pressures on increasing electricity prices [112].

We investigate selected factors affecting electricity prices and consumption in Slovenia during the period of electricity market liberalization.

3.2. Methodological Approach

Different approaches have been developed in the literature to estimate drivers of electricity consumption and electricity prices for industry and households [113–116]. We apply a regression analysis. Our dependent variables were electricity prices for industry and households, respectively, and electricity consumption by industry and households. The focus was on the Slovenian energy market situation (prices) in relation to the EEX market in Leipzig [117]. In Slovenia, electricity prices during electricity market deregulation and price liberalization were based on those achieved in the EEX market, which was considered the reference energy exchange market for Europe due to its size and volume of energy sold (liquidity).

Currently, data on energy exchange prices can be obtained from the South Pool BSP Stock Exchange in Slovenia. The Slovenian BSP energy stock exchange market has developed and become liquid at the daily level of trading [118].

We examined the effects of explanatory variables on the electricity consumption and electricity prices achieved in Slovenia. The Slovenian electricity market was studied in relation to the EEX market.

The statistical testing and regression models were estimated using the Statistical Package for the Social Sciences (IBM SPSS software package) [119,120], which provides standardized regression coefficients and non-standardized regression coefficients for regressions.

3.3. Data

Data on average monthly electricity prices for industry and households in Slovenia, respectively, and electricity consumption by industry and households in Slovenia were obtained from the Statistical Office of the Republic of Slovenia, SI-STAT [121]. Electricity price data were deflated by price indices with a constant base. Data were obtained from the SI-STAT. The same source of data was used for the following explanatory variables: monthly gross salary in Slovenia, which was deflated by consumer price index (CPI) with a constant base; monthly value of gross domestic product deflated by CPI for each month considered; industrial production index with a constant base; daily maximum (peak) power of electricity production achieved in Slovenian power plants; and average monthly air temperatures.

A dummy variable for electricity market deregulation and price liberalization takes the value equal to one = 1 for the months with these events, and zero otherwise. Two separate dummy variables were created for the impacts of electricity market liberalization on the industry and household electricity segments.

The achieved auction prices for cross-border transmission grid capacities represent the monthly average achieved prices at auctions for cross-border transmission grid capacities, namely on the route Austria–Slovenia. The monthly average was calculated from the daily achieved prices at auctions. Cross-border auction grid prices and data on daily maximum electricity power were obtained from Austrian Power Grid [122]. The other cross-border routes between Slovenia with other neighboring countries have been less relevant: cross-border transmission grid prices with Croatia have been very low, with Italy, they have largely been one-way trade with Slovenian export of the electricity to Italy, and with Hungary, cross-border transmission grid capacities have been established since October 2020. Since then, the cross-border transmission grid capacities have been established with each of the Slovenian neighboring countries.

The price of electricity on the EEX market represents the monthly price on the EEX market for the baseload energy. The monthly average was calculated as the average of the settlement prices. The variable was deflated by CPI for each month considered. Electricity prices on the EEX market were obtained from the EEX [117].

The price of CO_2 emission coupons represents the monthly price on the EEX (CARBIX) market. The monthly average was calculated from daily data for the period of each month. The variable was deflated by CPI for each month considered. Data were obtained from the EEX [117]. Other energy products are also traded on the EEX market, such as natural gas, coal and CO_2 emission coupons.

The price of natural gas represents the average monthly price of natural gas on the EEX (NGC) market. The variable was deflated by CPI for each month considered. Data on natural gas prices were obtained from the Slovenian company Goeplin, a trader of natural gas, and from EEX [117].

The price of coal represents the monthly market price of coal for Europe. The variable was deflated according to CPI for each month considered. Data on coal prices were obtained from EUROCOAL [123].

The price of Brent oil represents the average monthly price of "Brent" oil, which was deflated by CPI for each month considered. Data on the price of Brent oil were obtained

from the Slovenian company Petrol, a trader in oil derivatives, natural gas and other energy sources.

The specific analyzed period of liberalization was from January 2000 to December 2011. This gave, on a monthly basis, 144 observations. The analyzed period was selected due to two main reasons: first, the focus of the analysis was on the specific months in the periods of the introduction of the electricity market deregulation and price liberalization for industry and households in Slovenia in relation to the EEX market. Second, the analyzed period also covered Slovenian integration into the EU in May 2004. Consequently, the Slovenian electricity consumption by industry and households, and electricity prices for industry and households were adjusted to the internal domestic and external EEX market as well as other drivers, which are analyzed in this study.

3.4. Summary Statistics of Variables

Table 1 presents summary statistics (the mean, minimum and maximum values) of variables used in the regression analysis. The price of electricity on the EEX stock exchange market fluctuated. On average, it was higher than electricity prices for electricity sold to Slovenian industry and households. In addition, Slovenian industry paid on average less than Slovenian households. The difference in price can be explained by average consumption, which was on average four times higher in industry than in households.

Table 1. Summary statistics of variables.

Variables	N	Minimum	Maximum	Mean	Std. Dev.
Price of electricity on the EEX (EUR/MW)	139	15.38	91.39	40.07	16.03
Price of Brent oil (EUR/barrel)	144	24.50	86.06	47.56	15.13
Price of coal (EUR/t)	144	30.27	168.94	64.92	27.52
Price of natural gas (EUR/MWh)	144	0.22	0.50	0.36	0.07
Price of CO_2 emission coupons (EUR/t)	84	0.02	27.98	13.90	7.69
Consumption of electrical energy in industry in Slovenia (GWh)	144	4966.00	7468.00	6240.75	797.62
Consumption of electrical energy in households in Slovenia (GWh)	144	0.070	0.118	0.091	0.012
Average price of electrical energy in industry in Slovenia (EUR/MW)	144	0.052	0.101	0.074	0.012
Average price of electrical energy in households in Slovenia (EUR/MW)	144	0.070	0.118	0.091	0.012
Maximum daily (peak) power of electricity production in power plants in Slovenia (MW)	120	64.85	91.45	76.39	8.82
Cross-border transmission grid capacity (EUR/MWh)	71	0.00	36.75	3.50	7.78

N—number of observations and Std. Dev.—standard deviation. Source: authors' calculations.

Among the prices for the three primary energy sources, coal was the most expensive. The prices of coal, natural gas and oil were volatile by the individual years. A substantial difference between the minimum and maximum values was also observed for the price of CO_2 emission coupons and price of cross-border transmission grid capacity. Both tended to increase over time. The maximum daily power of electricity power plants changed by years due to investments in production capacities and natural conditions, particularly relevant for some renewable sources of energy such as electricity from hydro energy, which is important in Slovenia [83,124].

4. Results

Our results on testing the set hypotheses are presented and explained in three steps. First, we present and explain primary sources of energy prices, electricity prices on the EEX market (H1) and the Slovenian market (H2: H2a for industry and H2b for households), and electricity consumption in Slovenia (H3: H3a for industry and H3b for households). Graphical presentation and a regression analysis were applied. Second, we present and explain the regression results on the effects of electricity consumption and electricity

market liberalization on electricity prices for Slovenian industry (H4a), and the effects of the electricity consumption, electricity market liberalization, daily maximum electricity power, monthly salaries, and cross-border grid prices on electricity prices for Slovenian households (H4b). Finally, we present and explain the regression results on the drivers affecting electricity consumption by industry (H5a) and households in Slovenia (H5b).

4.1. Primary Energy Prices, Electricity Prices, and Electricity Consumption

First, we examined the set H1, whether electricity prices on the EEX market are significantly related to primary sources of energy (coal, natural gas, and oil) prices, CO_2 emission coupon prices and variations in air temperature.

Primary sources of energy prices are one of the most significant factors affecting electricity prices in continental European markets. We expected a positive association between independent variables, i.e., primary sources of energy prices and CO_2 emission coupons prices, and the dependent variable, i.e., electricity prices on the EEX market. The impact of variations in air temperature on electricity prices can be mixed because electricity consumption can increase due to both extremes of air temperature: during low temperatures in the cold winter period due to heating and during high summer temperatures due to air conditioning. We also examined whether there was any association between electricity consumption growth (demand for electricity) and the maximum installed capacity of power plants (supply of electricity) on the one hand and electricity prices on the other hand.

Figure 1 shows the differences in the selected variables for primary sources of energy prices achieved on the EEX market, as well as oscillations and the convergence tendency for prices of natural gas, oil and coal. These levels and patterns in development can be explained by the EU and global energy market developments driven by global supply and demand for energy, such as the effects of the growing Chinese economy on the energy markets [13,14,23–25,46,91,117]. Electricity prices achieved on the EEX market have not followed the developments in prices of the above-mentioned energy sources. Something similar applies to CO_2 emission coupon prices, the market for which was established later.

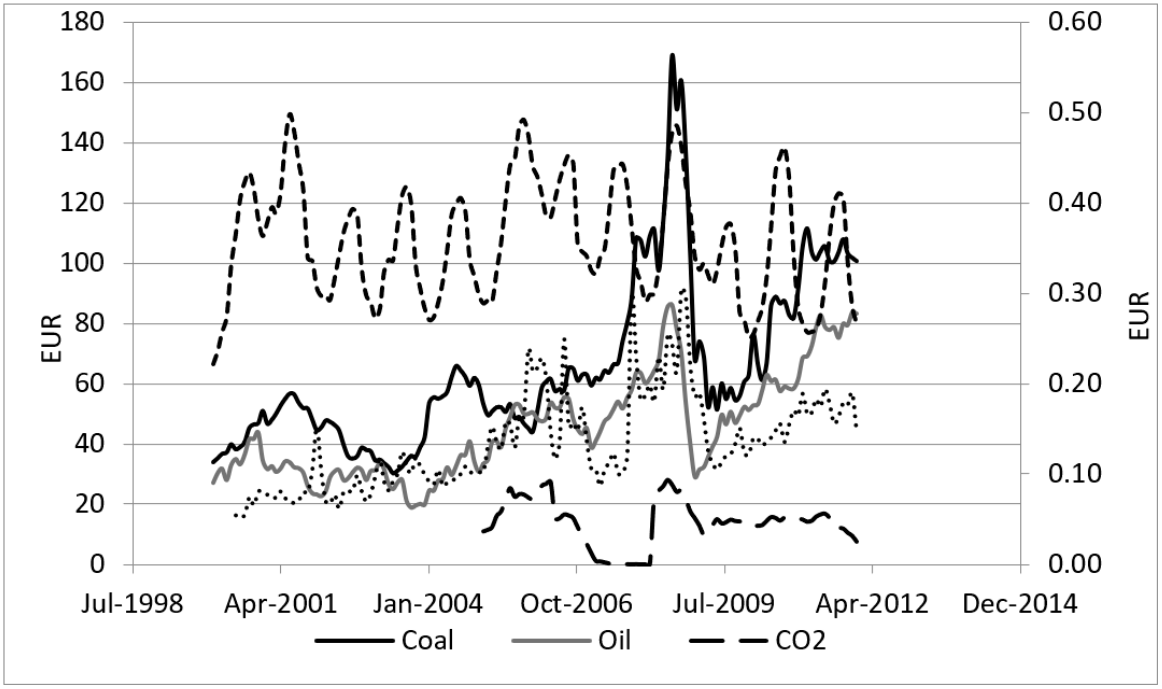

Figure 1. Primary sources of energy prices, CO_2 emission coupon prices, and electricity prices on the EEX market in the January 2000–December 2011 period. Note: Two vertical axes are adjusted to different absolute sizes of data. The gas prices are on the secondary axis (right vertical scale). The rest are on the primary axis (left vertical scale). Source: authors' graphical presentation based on data from [117,118,121–123].

The effect of primary sources of energy prices and CO_2 emission coupon prices and variation in air temperature on electricity prices achieved on the EEX market was tested with a regression analysis (Table 2). The estimated regression model proved to be sufficiently accurate to forecast electricity prices on the EEX market. The statistical significance was high enough to accurately explain the dependent variable with independent variables (p = 0.000). The model specified explained 58.0% of variation in the dependent variable. This relatively low adjusted R^2 suggests the presence of some other, non-specified explanatory variables and exogenous factors that are driving electricity prices on the EEX market.

Table 2. Regression of the effect of primary sources of energy prices, emission coupon prices, and variation in air temperature on electricity prices on the EEX market.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	−2.428	6.585		−0.369	0.713
Gas prices	91.896	20.561	0.444	4.469	0.000
Coal prices	0.296	0.036	0.584	8.112	0.000
CO_2 emission coupon prices	0.509	0.139	0.278	3.649	0.000
Air temperature	−0.944	0.190	−0.472	−4.963	0.000

Dependent variable: electricity prices on the EEX market. N = 144. Adjusted R^2 = 0.58. F statistic = 29.6. Source: authors' estimations.

The calculated statistically significant regression coefficients showed that prices of individual primary energy sources had a significant effect on electricity prices achieved on the EEX market. For all of them, the statistical significance (p-value) was less than 0.05. We cannot reject, and thus we confirm, the set H1 that electricity prices on the EEX market are significantly related to prices of primary energy sources, CO_2 emission coupon prices and variations in air temperature.

Second, we examined the set H2. H2a: whether electricity prices for industry in Slovenia were significantly associated with primary sources of energy prices, CO_2 emission coupon prices, cross-border grid prices and the industrial production index (Table 3). H2b: whether electricity prices for households in Slovenia were significantly associated with prices of primary energy sources, variations in air temperature, cross-border grid transmission capacity prices and monthly gross salary (Table 4). All included regression coefficients are statistically significant. The set H2a cannot be rejected. The electricity prices for industry in Slovenia were driven by their input cost prices.

Table 3. Regression of the effect of primary sources of energy prices, cross-border grid prices, CO_2 emission coupon prices, and the industrial production index on electricity prices for industry in Slovenia.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	0.067	0.005		13.203	0.000
Gas prices	0.022	0.008	0.220	2.684	0.009
CO_2 emission coupon prices	0.000	0.000	−0.484	−4.826	0.000
Cross-border grid prices	0.000	0.000	0.337	3.399	0.001
Industrial production index	0.000	0.000	0.168	2.284	0.025

Dependent variable: electricity prices for industry in Slovenia. N = 144. Adjusted R^2 = 0.61. F statistic = 33.2. Source: authors' estimations.
Dependent variable: electricity prices for industry in Slovenia. N = 144. Adjusted R^2 = 0.61. F statistic = 33.2. Source: authors' estimations.

While in the regression for electricity prices for industry in Slovenia there is a negative sign of regression coefficient (only for standardized coefficients) for CO_2 emission coupon prices, statistically significant regression coefficients are of mixed signs in the regression of electricity prices for households in Slovenia: the expected positive pertained to oil prices and monthly gross salary, but the negative pertained to gas and coal prices and cross border grid prices. The former suggests possible cross-substitution effects between primary sources of energy. Interestingly, variation in air temperature also had a positive effect on

electricity prices for households in Slovenia. These mixed results regarding testing the set H2a do not provide clear conclusions. The set H2a cannot be completely rejected, as the regression coefficients pertaining to oil prices and monthly gross salary are statistically significant, with a theoretically expected positive sign.

Table 4. Regression of the effect of primary sources of energy prices, cross-border grid prices, variation in air temperature, and monthly gross salary on electricity prices for households in Slovenia.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	0.038	0.003		13.020	0.000
Gas prices	−0.022	0.007	−0.121	−3.305	0.001
Coal prices	-8.563×10^{-5}	0.000	−0.201	−4.114	0.000
Oil prices	1.405×10^{-7}	0.000	0.205	3.911	0.000
Air temperature	2.351×10^{-7}	0.000	0.142	3.949	0.000
Cross-border grid prices	-2.673×10^{-7}	0.000	−0.130	−4.886	0.000
Monthly gross salary	4.716×10^{-5}	0.000	0.929	22.259	0.000

Dependent variable: electricity prices for households in Slovenia. N = 144. Adjusted R^2 = 0.90. F statistic = 224.4. Source: authors' estimations.

Third, we examined the set H3. H3a: whether electricity consumption in industry in Slovenia is significantly associated with primary sources of energy prices, CO_2 emission coupon prices, variation in air temperature, daily maximum electricity power and industrial production index. H3b: whether electricity consumption in households in Slovenia is significantly associated with CO_2 emission coupon prices, daily maximum electricity power, cross-border grid prices, monthly gross salary and gross domestic product. We separately analyzed industrial and household electricity consumption.

Table 5 for industrial electricity consumption shows that the regression coefficients are statistically significant with mixed theoretical meaning. While an increase in electricity consumption by industry with an increase in the industrial output and daily maximum electricity power is expected, a positive association with cross-oil and gas prices suggests that oil and gas are substitutes for electricity consumption in industry. Therefore, we can expect electricity consumption by industry to increase when the prices of oil and gas increase. An increase in CO_2 emission coupon prices decreases electricity consumption by industry. Similarly, a negative association is found between electricity consumption by industry and variations in air temperature. According to statistically significant associations and, as explained, the signs of the regression coefficient, we cannot reject the set H3a. These findings point to certain efforts to manage costs and ensure energy efficiency in the industry sector, which can eventually decrease electricity consumption by industry.

Table 5. Regression of the effect of primary sources of energy prices, CO_2 emission coupon prices, daily maximum electricity power, and industrial production index on electricity consumption by Slovenian industry.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	−4919.567	1408.256		−3.493	0.001
Gas prices	8203.017	1484.417	0.598	5.526	0.000
Oil prices	18.487	7.264	0.282	2.545	0.013
CO_2 emission coupon prices	−57.146	10.697	−0.472	−5.342	0.000
Air temperature	−54.165	13.496	−0.409	−4.014	0.000
Daily maximum electricity power	0.087	0.015	0.652	5.954	0.000
Industrial production index	23.537	6.657	0.280	3.535	0.001

Dependent variable: electricity consumption by industry in Slovenia. N = 144. Adjusted R^2 = 0.57. F statistic = 19.3. Source: authors' estimations.

Table 6 for household electricity consumption shows that all included regression coefficients are statistically significant. As expected, there is a positive association between monthly gross salary and gross domestic product as economic variables on the one hand, and household electricity consumption on the other. A positive sign of the regression coefficient pertaining to CO_2 emission coupon prices is less clear, as it is more likely that they contribute to increasing costs and prices of electrical energy. As expected, there is a negative association between the daily maximum electricity power and cross-border grid prices on the one hand, and household electricity consumption on the other. Both increase costs and electricity prices, and thus reduce electricity consumption by households. Based on the regression results, the set H3b is largely, except for CO_2 emission coupon prices, consistent with theoretical expectation.

Table 6. Regression of the effect of CO_2 emission coupon prices, cross-border grid prices, daily maximum electricity power, monthly gross salary, and gross domestic product on electricity consumption by Slovenian households.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	2776.666	170.883		16.249	0.000
CO_2 emission coupon prices	1.754	0.660	0.140	2.658	0.010
Daily maximum electricity power	−0.005	0.001	−0.337	−3.928	0.000
Cross-border grid prices	−3.295	0.719	−0.248	−4.582	0.000
Monthly gross salary	0.189	0.049	0.292	3.870	0.000
Gross domestic product	0.011	0.003	0.353	3.719	0.000

Dependent variable: electricity consumption by households in Slovenia. N = 144. Adjusted R^2 = 0.86. F statistic = 104.5. Source: authors' estimations.

4.2. Electricity Market Liberalization, Electricity Prices, and Electricity Consumption

First, we examined the set H4. H4a: whether there was any association between electricity prices for industry in Slovenia and electricity consumption by industry and electricity market liberalization for industry. H4b: whether there was any association between electricity prices for households in Slovenia and electricity consumption by households, daily maximum electricity power, cross-border grid prices, monthly gross salary and electricity market liberalization.

Table 7 shows that, unexpectedly, there is a positive association between electricity prices for industry on the one hand and electricity consumption by industry and electricity market liberalization for industry on the other. This, in turn, shows that electricity market deregulation and price liberalization did not reduce electricity prices as expected, and that higher electricity consumption by industry resulted in higher electricity prices for industry. While the regression coefficients are statistically significant, they are of the opposite sign than expected. Therefore, the set H4a can be rejected.

Table 7. Regression of the effect of electricity consumption by industry and electricity market liberalization on electricity prices for Slovenian industry.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	−0.582	0.624		−0.934	0.352
Dummy for liberalization	0.215	0.019	0.599	11.414	0.000
Electricity consumption by industry	0.543	0.072	0.398	7.574	0.000

Dependent variable: electricity prices for industry in Slovenia. N = 144. Adjusted R^2 = 0.63. F statistic = 122.8. Source: authors' estimations.

Table 8 shows that there is a positive association between electricity prices for Slovenian households on the one hand and maximum daily electricity power, electricity consumption by households, monthly gross salary, and a dummy variable for electricity market liberalization for households on the other. There is a negative association with cross-border

grid prices. These findings are mixed, as only the regression coefficients pertaining to maximum daily electricity power and monthly gross salary are theoretically of expected sign. Electricity market deregulation and price liberalization did not reduce electricity prices for households as expected. It seems that increased demand and income effects prevail over others. Higher electricity consumption by households and higher gross salaries resulted in higher electricity prices for households. Therefore, the set H4b can largely be rejected.

Table 8. Regression of the effect of electricity consumption, electricity market liberalization, daily maximum electricity power, monthly gross salaries, and cross-border grid prices on electricity prices for Slovenian households.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	−10.139	3.811		−2.661	0.010
Daily maximum electricity power	0.286	0.108	0.286	2.659	0.011
Cross-border grid prices	−0.009	0.004	−0.212	−2.601	0.012
Electricity consumption by households	1.091	0.410	0.361	2.661	0.010
Monthly gross salary	0.373	0.112	0.444	3.321	0.002
Dummy for liberalization	0.062	0.025	0.333	2.533	0.014

Dependent variable: electricity prices for households in Slovenia. N = 144. Adjusted R^2 = 0.77. F statistic = 38.4. Source: authors' estimations.

Despite the market deregulation and price liberalization and expected increase in competition in the Slovenian electricity markets, the real prices of electricity did not decline, but there was an increasing trend in the real prices of electricity. This finding is valid both for electricity prices in industry (H4a) and electricity prices for households (H4b).

4.3. Drivers Affecting Electricity Consumption by Industry and Households

With a regression analysis, we tested the set H5 on the factors affecting electricity consumption by Slovenian industry and households. We examined whether there was any association between electricity prices on the EEX market and electricity consumption by Slovenian industry and households.

Table 9 shows that, as expected, there is a positive association between electricity consumption by industry and industrial output. This means that the higher the industrial output, the higher the electricity consumption by industry. A negative association between electricity consumption by industry and gross domestic product is less clearly explained. The increase in Slovenia's gross domestic product during the same period did not increase electricity consumption by industry. It could be due to the restructuring of industry towards greater energy efficiency. There was a positive association between electricity consumption by industry and electricity prices on the EEX market, electricity prices for industry, and a dummy variable for electricity market liberalization for industry, respectively. While statistically significant, the signs of the regression coefficients are inconsistent with our theoretical expectations regarding a sign for the direct price elasticity of demand. Electricity market liberalization for industry resulted in an increased electricity consumption by industry. Together with the increase in electricity prices for industry, electricity consumption by industry also increased. Based on these mixed results of the regression coefficients, we can reject the set H5a for electricity consumption by industry in Slovenia.

Table 10 shows that there is a negative association between electricity consumption by households and electricity market liberalization for households, which occurred after mid-2007. After that time, Slovenia's economy also slipped into a recession. As expected, electricity consumption by households was affected by the increase in monthly gross salaries. What is surprising is that the increase in electricity prices on the EEX market and particularly the increase in electricity prices for households in Slovenia resulted in increased consumption by Slovenian households. Based on these mixed results, we can reject the set H5b for electricity consumption by households in Slovenia.

Table 9. Regression of the effect of electricity prices on the EEX market, average electricity prices for Slovenian industry, electricity market liberalization, gross domestic product, and industrial production index on the one hand, and electricity consumption by Slovenian industry on the other.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	11.447	0.758		15.107	0.000
Electricity prices on the EEX	0.088	0.031	0.269	2.808	0.006
Electricity prices for industry	0.667	0.063	0.881	10.505	0.000
Dummy for liberalization	0.062	0.030	0.233	2.037	0.044
Industrial production index	0.302	0.081	0.281	3.717	0.000
Gross domestic product	−0.711	0.082	−1.131	−8.653	0.000

Dependent variable: electricity consumption by industry in Slovenia. N = 144. Adjusted R^2 = 0.56. F statistic = 35.9. Source: authors' estimations.

Table 10. Regression of the effect of electricity prices on the EEX market, average electricity prices for Slovenian households, electricity market liberalization, and monthly gross salary on the one hand, and electricity consumption by Slovenian households on the other.

Model	Non-Standardized Coefficients		Standardized Coefficients	*t*-Test	*p*-Value
	B	Standard Error	Beta		
Constant	5.563	0.190		29.340	0.000
Electricity prices on the EEX	0.032	0.010	0.186	3.145	0.002
Prices for households	0.131	0.058	0.234	2.247	0.026
Monthly gross salary	0.245	0.046	0.661	5.269	0.000
Dummy for liberalization	−0.020	0.009	−0.145	−2.179	0.031

Dependent variable: electricity consumption by households in Slovenia. N = 144. Adjusted R^2 = 0.82. F statistic = 158.4. Source: authors' estimations.

5. Discussion

Our analysis has focused on the investigation of the association between primary sources of energy prices on the one hand and electricity consumption and prices on the other, both in Slovenia and on the EEX market, including certain additional control variables.

After the initial period of deregulation or the period of gradual deregulation and liberalization of the electricity market in Slovenia, the electricity market is developing further in the connection between prices of primary sources of energy as influential factors in the electricity market on the formation of electricity prices. The price of electricity on stock exchanges reflects the movement of prices of primary sources of energy and the composition of production sources (representation of types of power plants) and efforts to move to a low-carbon society [125–127].

We have established that there is a positive association between electricity prices on the EEX market on the one hand and primary sources of energy prices and CO_2 emission coupon prices on the other. Primary sources of energy prices are one of the most significant factors affecting the price of electricity in continental European markets. Electricity prices on the EEX market are affected by prices of all primary sources of energy, CO_2 emission coupon prices, and variations in air temperature.

We also performed a regression analysis on the relationship between electricity prices for Slovenian industry and established that they were significantly affected by gas prices, cross-border connection grid prices, CO_2 emission coupon prices, and developments in industrial output. Electricity prices for Slovenian households are affected by gas, coal and oil prices, cross-border connection grid prices, and monthly gross salaries.

We also tested the effect of primary sources of energy prices, variations in air temperature, cross-border connection grid prices, daily maximum electricity power, and CO_2 emission coupon prices on electricity consumption by both industry and households. Based on our analysis, we came to the following findings and conclusions:

First, electricity consumption by Slovenian industry is affected by gas and oil prices, variations in air temperature, CO_2 emission coupon prices, daily maximum electricity power, and developments in industry output. The higher the air temperature or higher the CO_2 emission coupon prices, the smaller the electricity consumption. CO_2 emission coupon prices increase costs of electricity supply and electricity prices which, due to direct price elasticity, reduces electricity consumption. However, in the case of the air temperature with climate change, there is an increasing trend in electricity demand and electricity consumption when air temperature increases above a certain interval from a warm to too hot temperature. In such circumstances, air conditioning is used, which increases electricity demand and electricity consumption. There is a positive association between other variables and electricity consumption by industry. The importance of industry in electricity consumption and its driving forces is relevant for science, policy, and practice. This finding is also in line with some previous studies [12–14,41].

Second, electricity consumption by Slovenian households is positively affected by CO_2 emission coupon prices, monthly gross salaries, and gross domestic product. The higher the aforementioned variables, the higher the electricity consumption by households. These findings are consistent with theoretical expectations in the set hypotheses. With the liberalization of the electricity market for households, the opening up of electricity prices to competition on the domestic electricity market was completed in Slovenia. The gradual liberalization has followed a similar path to some other EU and non-EU developed and emerging market economies [11,16,17,25,38–47,87,97].

Third, the conclusion of contracts on electricity supply in Slovenia is statistically significantly connected to electricity prices on the EEX market in Leipzig. There is a positive association between the EEX prices and electricity prices for Slovenian industry and households. This is mainly explained by the fact that Slovenia is a transit country, for which reason electricity prices to final consumers are also affected by the price of cross-border grid capacity. The latter is defined through auctions and can be very volatile, depending on the weather conditions and other factors. Additionally, not inconsiderable is the fact that the government has been affecting the final electricity price by introducing new duties which depend on consumer installed capacity and electricity consumption. The importance of spatial market and price integration and the role of government policies have also been identified by some previous studies [12,19,96].

Fourth, the effect of electricity consumption and liberalization on electricity prices for Slovenian industry and households is also statistically significant. The empirical results confirmed that electricity demand and electricity market liberalization had driven electricity price increases both for industry and households.

Electricity prices on the EEX market have a statistically significant effect on electricity consumption by Slovenian industry and households. Electricity consumption increases almost proportionally to electricity prices on the EEX market. This holds true for both industry and households. This finding suggests some level of integration of domestic with regional electricity markets, and their impact did not discourage electricity consumption. This is an issue that should be considered in the forecasting of electricity consumption in the future [44,81,104,105,114–116,128–130].

Fifth, three stages of market deregulation and price liberalization in the Slovenian transition electricity markets have been analyzed by the included dummy variables: the years with electricity market liberalization for industry equal to one and zero otherwise for the years before the liberalization, and the years with electricity market liberalization for households equal to one and zero otherwise for the years before the liberalization. The empirical results confirmed that electricity market liberalization increased electricity prices for both industry and households, while the effect of electricity market liberalization on electricity consumption was mixed: electricity consumption increased in industry and declined in households.

Finally, as regards the electrical energy market, Slovenia is relatively self-sufficient, but still uses electricity prices achieved on the EEX market in Leipzig as the basis for deter-

mining its own electricity prices. With this, fluctuations in primary sources of energy prices, such as coal, natural gas and oil, are transferred to electricity prices applicable in Slovenia. Further market, price and cross-price integration can lead to a greater development of the European single market in electricity and energy [16,17,89,96,97].

The overall merit of the results and findings can be compared with another country's analysis results. The pricing in Slovenia was carried out based on prices set by the electricity producers to industry and retail traders to households that coincided with stock market movements. This has not been always the case in some other EU countries, especially not at the beginning of electricity market deregulation and price liberalization. For example, the electricity market has been rather well developed in the Netherlands [36,37], but less so in some other transition countries and emerging market economies such as Romania [131,132]. However, it is expected that the electricity markets will converge and become more integrated, with greater similarities and more common features than different patterns in development. Moreover, some specificities in price determination and specificities in electricity consumption will more likely remain due to country-specific factors in electricity supply and electricity demand. Different sources of electrical energy on the supply side with renewable sources of energy and electricity consumption on the demand side are dependent on country-specific natural energy factor endowments and weather conditions on the one hand, and the structure of the economy and business and its level of economic development and incomes on the other. These country-specific supply-side and demand-side characteristics of electricity supply and electricity demand by industry, businesses, and households can lead to price volatilities of different frequencies. Cross-country electricity integration can be a potential factor that can contribute to their greater market and price stability [133–135].

The findings regarding the regression model specification variables and their implications can be tested for their validity and robustness in the broadest context of the newest and emerging advanced methodological approaches, data mining and data developments from various sources with an increasing role of artificial intelligence based on self-adaptive decomposition and heterogeneous ensemble learning [136], neural networks [137–139], and using artificial neural network-based customer profiles in smart grids [140]. Among issues for research in the future can also be to investigate the most recent and emerging challenging subjects, such as impacts on electricity consumption and the market pricing of energy in relation to renewable sources of energy [141–143] and various exogenous shocks such as ancillary services during the pandemic of the COVID-19 crisis [144].

A greater reliance on locally produced renewable sources of energy such as electricity produced from solar energy can be very relevant and important for investments and local self-sufficiency with electrical energy, particularly in Central and southern Mediterranean Europe, including in Slovenia [145–148]. An important factor in electricity markets and electricity consumption can be energy-saving strategies, policies, and practices [149–151].

6. Conclusions

6.1. Contributions and Main Findings

This study contributes an applied approach and empirical results on the driving forces of electricity prices and electricity consumption by industry and households during electricity market liberalization. In addition to electricity market liberalization, the studied period covers the EU enlargement to the east in 2004, including Slovenia. The studied country, Slovenia, is important due to its geographical location for European electricity networks and special market and price integration between Central European (Hungary), western European (Austria), South European (Italy), and south-eastern European (Croatia) countries.

The study confirmed the importance of both internal domestic and external regional and international driving forces for the formation of electricity prices and their implications on electricity consumption in industry and households. The single market is the core of today's EU economy, with aims to be established for electricity and other energy markets. Households and businesses can choose their own supplier of electricity and natural gas.

One of the conditions for the emergence of the single market was market liberalization. With the liberalization of the electricity sector, competition has also emerged in Slovenia, albeit between majority state-owned companies. Despite the fact that Slovenia is relatively self-sufficient with electricity, the electricity exchange EEX market was used as the basis for electricity price formation during the electricity market deregulation and electricity price liberalization. Thus, fluctuations in the prices of primary energy sources, such as coal, natural gas, oil, and others, were transferred to the price of electricity in Slovenia. The price of electricity in Slovenia was linked to the stock exchange price of electricity, which was influenced by the price of primary energy sources. The final price of electricity in Slovenia was influenced by the price on the EEX stock exchange. Slovenia is a transit country, and the formation of the final price of electricity can be influenced by the price of cross-border transmission grid capacities. This is determined through auctions and can fluctuate greatly due to weather and other factors. The state intervened in the final price by introducing new charges related to the connected power of customers and electricity consumption. Different electricity prices between providers may be due to the purchase of electricity in different periods with different stock market prices. With the higher consumption of electrical energy, pressures for increases in electricity prices can be expected if the production and supply of electricity does not follow the increase in demands.

6.2. Study Limitations and Issues for the Research in the Future

This study applied regression analysis and does not cover the most recent developments following the global economic and financial crisis, and the most recent global health (COVID-19) crisis. One of the main research limitations is data obtained from various sources, including from companies operating in the energy sector. Due to the sensitivity of the data, it is likely that their absolute values, but not the dynamics, were partly adjusted to protect business secrets. In addition, electricity prices were used as final customer prices. In addition to the market price, the final prices also included the price for the use of the networks, excise duties and other contributions. The regulated part of the price of electricity has undergone the greatest changes through the process of the liberalization of the electricity market. Thus, it is likely that in addition to stock market prices, the movement of electricity prices was also influenced by the state through its institutions. By setting a regulated part of the price of electricity, it maintains prices at certain levels and thus eliminates the effects of market liberalization and competition. The time of crisis in the industry affects the amount of electricity consumed, which in turn affects the stock market and the final price of electricity. For household customers, the crisis is mainly reflected in the replacement of energy sources, namely as a transition to higher electricity consumption (a more favorable price of thermal kWh from electricity compared to the price of thermal kWh from other energy sources), and delays in payment. As part of promoting the use of cleaner energy sources, the state subsidizes the purchase of heat pumps for heating homes and domestic hot water.

These are issues for the research in the future, using most recent available data and various advanced methodological and empirical approaches to address specific countries' and cross-countries' comparative approaches. An interesting extension would be studying dynamic and rapidly developing scientific, policy and practical challenges regarding electricity prices and electricity demands by industry and households in a cross-country or panel data analysis.

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