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REGIONAL ELECTRICITY TRADE IN SOUTH EAST EUROPE – FINDINGS FROM A PANEL STRUCTURAL GRAVITY MODEL[4]

The paper discusses whether the electricity trade in South East Europe in 1990-2019 is driven by fundamentals or, like other commodities, one could argue for a speculative movement of electricity flows motivated by factors such as prices. We employ a panel structural gravity model on the example of Bulgaria, Romania, Serbia, Republic of North Macedonia, Greece, Turkey, and Hungary to study the dependence between net exports, generation, and consumption of electricity, as well as the regulations in the field of exporting electricity. We find that domestic consumption of electricity is a much stronger factor than the generation when considering foreign trade in electricity. The construction of power capacity in the countries considered is much more oriented towards the domestic market, which results in an underdeveloped interconnection between them. This is a serious obstacle to the liberalization on the electricity market in the region and its integration into pan-European market structures. It also creates conditions for maintaining higher and volatile electricity prices and, consequently, negatively affects economic development.
Keywords: foreign trade in electricity; panel structural gravity model; electricity market regionalization
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Introduction

The opportunities for trading in electricity can be studied in two aspects. Firstly, as regards the electricity transactions on the domestic market, and then on the international markets –

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through the market couplings of power exchange operators and electricity system operators that comply with uniform regulations. With the accelerated liberalization and creation of a common energy market in the EU, in fact, the differentiation of the two markets is becoming increasingly difficult due to the specificities of electricity – an undifferentiated product with the same quality (that is not influenced by different sources of generation) and the impossibility of storage, despite the progress of new technologies in this field. This circumstance raises interest on the current conditions of the electricity markets in South East Europe as regards the cross-border trade in electricity. Another interesting research point is the extent to which the electricity market liberalization processes currently have a positive effect on foreign trade in electricity, or it is rather dependent on the local specificities imposed by its generation and consumption.

The issue is also becoming increasingly relevant given the high price volatility of the energy markets, driven mainly by seasonal factors, and the geopolitical risks from early 2022, which have a direct impact on the processes of electricity markets in South East Europe. While household consumption of electricity is more seasonally volatile, industry demand is more predictable and with smaller annual changes. Meanwhile, the low price elasticity of demand is determined by the lack of substitutes (Filippini, 1999). It leads to problems in the functioning of the electricity markets: substantial price jumps and an increase in the ‘market power’ of certain market participants (Kirschen, 2003), which the liberalization of the electricity market seeks to cope with.

The purpose of the paper is to test the extent to which net exports of electricity in 1990-2019 in Bulgaria, Romania, Serbia, Republic of North Macedonia, Greece, Turkey, and Hungary depend on the local generation and domestic consumption of electricity, using a panel structural gravity model. We aim to find out the impact of the fundamental local factors on the foreign trade in electricity and the extent to which we can talk about a separate cross-border electricity market in South East Europe, or whether it is subject to internally determined processes in the field of electricity. This is important given the fact that international trade in electricity makes it possible to avoid, maintaining a large reserve capacity and importing electricity from neighbouring countries, which have a comparative advantage in its generation; in this way, the benefits of liberalization of the electricity market are to be realized.

The next section of the paper discusses the specificities of electricity trade against the background of ongoing processes of liberalization in the European Union. Section 3 reviews research on the topic and the features of modelling foreign trade in electricity through the gravity model of trade. Section 4 presents the structure of a panel structural gravity model, which we adapt and test considering the specificities of the electricity markets in South East Europe. In conclusion, we comment on the econometric results and draw conclusions about the challenges to the liberalization of the electricity sector in the region.

Specificities of the Electricity Trade in the EU in the Context of the European Union's Strategy on Energy Sector Development

A review of the economic research clearly highlights the leading importance of the reforms carried out by the EU Member States in the energy sector – initially at a national level, targeted at eliminating the natural national monopolists, liberalizing the market, and ensuring the security of supply. Aiming at improving efficiency at the microeconomic level, the structural measures were implemented with the vision that liberalized markets automatically create competitiveness and economic growth (Vlahinić-Dizdarević, Galović, 2007).

The first major reforms in this regard took place in the United Kingdom in the 1990s, when the electricity supply activity was subject to privatization and electricity generation was allocated among private companies. The focus of the reforms was on the generation and trading of electricity, so to create independent producers that compete with the state monopolies already established over the years (Rothwell, Gómez, 2003). The main argument was that this would lead to economic benefits and lower prices for consumers (Kirschen&Strbac, 2004). In 1998, the World Trade Organization pointed out that problems could arise due to the partial consideration of electricity only as a commodity or only as a service when liberalizing the market. For this reason, the distinction between the generation, transmission and distribution of electricity can create an imbalance in the drafting of trade rules for different liberalized market segments in terms of trade and some business practices (Pineu, 2004). The possibility of the emergence of double standards in the reformation of the sector imposes the use of uniform trade rules in the liberalization (Eberhard, 2003), which are also essential for the cross-border trade exchange of electrical energy.

The turning point in the development of EU guidelines on electricity markets was the adoption of the first directives in 1996, known as the First Energy Package, concerning the liberalization of the energy and gas Sectors. By 1998, they had been transposed into the Member States' legal systems and aimed to gradually open the local markets to competition. Pollitt (2009) points out that the theoretical basis of EU reforms on the electricity market is based on the theory of free competition that aims to increase competition in generation and retail at a national market level, reduce the market share of monopolists and create regional markets.

During this period, the first serious challenge to the liberalization of the electricity market in the EU emerged – the existing different views on the market mechanisms and market design of the electricity market. Some of these challenges stemmed directly from the structure of the EU itself. In the USA, electricity trading is carried out through the so-called integrated market, where the system operator centrally optimizes the demand and supply of electricity in the network. In the EU, a different market model based on exchange trading has been adopted, considering the differences in the electricity sector of individual Member States in building the Single Market (Cramton, 2017).

Further directives were drafted in 2003 and were transposed into national legislation by 2004, but some provisions did not come into force until 2007. The adoption of this so-called Second Energy Package enabled industrial consumers and households to choose their own electricity and natural gas suppliers from a wider range of competitors. The third liberalization package was adopted in 2009 with the main goal of consolidating the electricity and natural gas markets and their transition from national to regional, and subsequently to pan-European ones. The idea is that the single market will lead to single demand and supply and prices, as has happened or is happening with the other markets for goods and services in the EU (Georgiev, 2014).

In recent years, the Global Powers have taken decisive steps in accordance with the Paris Agreement. The Green Pact of 2019, also known as the European Green Deal or the European Green Pact, is the EU's most ambitious climate strategy to date. Europe's goal is to become the first carbon-neutral continent by 2050, meaning no net greenhouse gas emissions in 2050. The European Green Pact affirms the European Commission's commitment to address the challenges related to the protection and conservation of the EU's natural environment, as well as the protection of the health and well-being of citizens.

Although between 1990 and 2018, the EU economy grew by 61% in nominal terms, it managed to reduce the greenhouse gas emissions only by 23%. The energy generation and consumption account for 75% of the EU's greenhouse gas (carbon) emissions; therefore, the reform of the energy system becomes the primary task for the climate goals set. To achieve the target for 2030, the update of the Renewable Energy Directive (RED II) proposes to increase the overall target for renewable energy use in the EU energy mix from the current 32% to a new level of 40%. By 2050, a target of 300 GW of wind energy from offshore installations and 40 GW of ocean energy in all the Union's seas is set.

Establishing a functioning internal energy market is seen as fundamental to three energy-related challenges: competitiveness (reducing costs for citizens and businesses), sustainability of the emissions trading mechanism and security of supply. To establish an internal energy market, priority was given to the unification of the technical standards necessary for the functioning of cross-border trade. In many countries, the technical standards differ, which hinders the interconnection of power grids. Support was also provided for identifying and building the missing infrastructure between the EU countries and the infrastructure needed to integrate renewable energy into a grid. Ownership unbundling of the companies responsible for the maintenance and operation of the grids and the companies for supply and generation was considered an important condition for improving competitiveness (European Commission, 2017).

However, it is worth noting that the international environment in terms of electricity generation and pricing is quite complex. In some Member States, in strong opposition to the fight against climate change, the electricity generation from coal receives significant subsidies, which not only favours the electricity generation with a strong negative impact on the environment, but also distorts pricing and financial and economic results in the electricity system (Miljević, Mumović, Kopač, 2019). On the other hand, EU countries follow their own strategies to support renewable energy sources, based on research that environmental protection policies in the field of electricity do not have a negative impact on economic growth (Venkatraja, 2021). Measures are needed and implemented to support emerging technologies, but this is contradictory to the policy of market liberalization and the goal of increasing the competitiveness of the European economy (Byanova, 2021). We can conclude that the electricity market only seems a competitive one, it does not guarantee equal opportunities for all participants and only capacities that receive subsidies are created (Georgiev, 2018). There is a lack of full integration and coherence in the EU energy policies, despite the increasingly important role of the external electricity market due to the growing demand for electricity from the transport sector and several production activities replacing the use of fossil fuels with environmentally friendly sources, based on renewable energy sources (RES). The results of the rehabilitation of residential buildings also remain controversial, which is the reason why the expected savings from the energy used by households for heating are not observed (Peneva, 2021).

Literature Review and Specificities in the Modeling of Electricity Trade

The regional integration, similar regulatory frameworks and lack of significant problems related to congestion in the electricity system and cross-border capacities make it possible for more in-depth research on international electricity trade to be done.

Several approaches exist in the professional economic literature that analyze electricity consumption and the factors that influence it. These models are directly related to the exports of electricity, as the domestic electricity consumption can be satisfied both by domestic generation and by imports. For this reason, the factors that determine the electricity consumption are also the factors that determine the opportunities a country to export electricity (Zlatinov, 2018). The electricity consumption is also strongly dependent on the macroeconomic fundamentals – it increases in direct proportion with the increase of incomes, the favourable conditions for economic sectors development and the improvement of the investment environment. That is why we are interested to investigate to what extent purely fundamental factors related to the generation and consumption of electricity also influence international electricity trade, or other factors and preconditions are stronger there.

The authors employ short-run and long-run approaches to studying electricity consumption. The most used of them is the final consumption method. An extended approach is the combination of econometric analysis and final consumption method[5] in which electricity consumption is addressed in different consumer groups. This method provides a better opportunity to analyze sectoral dependencies. The use of such models makes it possible to analyze the electricity consumption of households, industry, services, and the public sector based on the linkages with economic growth, electricity prices, population growth, effect of public and regulatory policies, climate conditions.

In general, the net electricity export depends on the electricity consumption and its prices (Hakkio, Nie, 2014). The generation, distance and transmission capabilities are considered as other important factors for electricity exports. The limits to trade relationships with the increase of distance between countries trading in electricity make it possible to use the gravity model of trade. This approach is based on the theoretical formulations of Anderson (1979) and Anderson & Van Wincoop (2003). In a traditional sense, the gravity model can be defined as one intuitively based on the economic logic that underlies its construction – the

[5] This approach is well-known in the economic literature and used extensively. Its applications as regards the foreign trade of Bulgaria are demonstrated by Stoevsky, G. (2009).

bigger the volume of production and the smaller the distance between the countries, the more they would trade with each other. As Anderson & Van Wincoop (2003) note, the gravity model essentially sets a demand function with constant elasticity of substitution.

Piermartini & Yotov (2016) point out that various effects arising from geography, demography, trade agreements, foreign direct investment, cross-cultural relations, etc., can be investigated through the gravity equation. As regards the international trade in electricity, the model can be employed by assuming that the closer the countries are and an interconnection between them is developed, the greater should be the transfer of electricity, other things being equal. In this way, the main advantages of the gravity model, described by Larch & Yotov (2016), can be utilized, including as regards the foreign flows in electricity:

1. Its intuitive nature (based on Newton's Law of Universal Gravitation);
2. The ability to apply at a macroeconomic and microeconomic level by including several countries, sectors, or companies;
3. Its high predictive accuracy varies between 60 and 90% when using aggregated data for different goods and services.

Relying on the intuitive nature of the gravity model, Antweiler (2016) constructed a model of bilateral international trade, representing the one-way and two-way electricity trade between some US states and Canadian provinces. The authors analyze data on the electricity generation in Canada by low marginal cost plants (HPPs and NPPs) with smaller changes in the output, the domestic consumption in the country, the exports to the USA, the seasonal changes and large profit margin. Based on the model of bilateral trade in electricity developed by Antweiler (2016), one can highlight some important features arising from the specificities of the electricity sector:

- trade is one-way when there is a strong comparative advantage in the generation of electricity and two-way when the comparative advantages between the trading partners are identical;
- trade is two-way when demand for exports fluctuates, and imports follow the gap in the load on the electricity transmission grid between the two countries;
- trading opportunities follow the changes in the electricity demand over time due to seasonal or local effects;
- differences in the size of countries also encourage cross-border trade;
- the volume of trade in electricity is subject to a much sharper decline than that of trade in other commodities;
- the elasticity of ordinary goods is about one, but of electricity it is twice as high because price is not the main factor that determines demand. This is also demonstrated by the analysis of Otsuka (2015) – when the price increases by 1%, the consumption of the industrial and service sectors in Japan changes by 0.15%;
- doubling the distance reduces foreign trade in electricity by a quarter due to system connectivity and various legal and regulatory barriers;

- the greater trade in electricity is impeded by the increased long-distance losses amounting to about 3.5% per 1000 km and the increase in the price of electricity, as a transmission fee must be paid.

Due to the heteroskedasticity in the model proposed by Antweiler (2016), Batalla et al. (2019) use the linear version of the gravity equation proposed by Santos-Silva and Tenreyro (2011). One can draw the following conclusions on cross-border trade in electricity based on the results of Batalla et al. (2019):

- electricity demand is driven by the importing country and not by the exporting country; this shows a strong link between economic activity and energy flows – the GDP of the exporting country is significantly lower than the GDP of the importing country[6];
- electricity prices matter in trading. If the export price of electricity increases by 1%, trade decreases by an average of 0.7%; the same increase in the importer's electricity prices increases trade by almost 1% on average. This result is in line with the standard situation of comparative advantage in international economics.

The models of Antweiler (2016) and Batalla et al. (2019), based on the gravity model of trade, also show that the price does not necessarily reflect the abundance of resources, as in the Heckscher-Ohlin concept. The price of the electricity traded depends on both the long-run comparative advantages and the short-run shortages, which often prove to be a decisive factor. Viewed as a homogeneous commodity, electricity can be assessed in a different way and therefore, the single price law is not valid. Thus, it is possible that pricing will reach very high levels (Antweiler, 2016).

Roy et al. (2000) view electricity as a commodity (based on the markets in Belgium, Germany, and France) that can be traded like all other commodities, but they note that some potential problems arise in the electricity market, such as:

- demand and supply of electricity must always coincide, which is the main reason why market factors cannot respond quickly to changing physical flows of electricity. This problem is called the balancing problem;
- grid restrictions, which are often unpredictable, reduce the possible transactions and create a problem with restrictions.

When studying electricity trading, researchers emphasize the role of the system operator, which is responsible for the reliability of the grid and the provision of additional services related to the security of supply and the quality of electricity. The system operator manages the market in real time, i.e., decisions are made and implemented immediately. Higher price stability can be achieved through bilateral agreements that are made for a longer period. Due

[6] Such a conclusion matters to the periodically appearing plans of Bulgaria to build Belene NPP, due to the possibilities for trading the generated quantities of electricity on the regional market. The high electricity prices in the summer of 2021 showed that the generation base of Bulgaria is, in practice, supported by the exports and not by the domestic consumption, where some of the large industrial producers suspended their generation facilities due to the unfavourable prices.

to the emergence of such challenges to the electricity system, Ji et al. (2016) use grid analysis to study the structure of interconnected electricity grids on a global scale. They aim to identify the national grids that are crucial for the stability of the global electricity transmission system, using data on the international electricity trade from 1990 to 2010. The network analysis shows that geographical proximity, political relations, and landscape have an important role in the formation of trade nodes of countries under the trade in electricity, which also points to the possibility of using the gravity equation. The analysis is applicable to the Eurasian power sub-grid, to which the EU countries belong. It also includes the largest number of countries that develop intensive mutual trade and form separate trading groups. The great dependence of some European countries on the trading partners in the export or import of electricity also comes to the fore.

It should be noted that, when considering trade in electricity, the conditions for its realization are developing much more dynamically than those for other commodities. This is due to the frequent changes in the market organization, which are related both to the economic, engineering, and legislative changes and to the rapid penetration of new technologies in the sector.

Model Specification of Net Electricity Exports in South East Europe Employing a Structural Gravity Model of Trade

The modified gravity equation to reflect the specificities of electricity trade flows has the following form:

$$NX_{i.j} = c + b_1 Y_i + b_2 Y_j + b_3 \tau_{i,j} + b_4 Reg_{i.j} + e_{i.j} \quad (1)$$

where:

$NX_{i.j}$ is the net exports of electricity;

Y_i and Y_j – the quantities of electricity generated in the two countries concerned;

$\tau_{i,j}$ – a variable reflecting the possibility for transmission of electricity;

Reg – the specific regulations imposed in foreign trade transmission of electricity.

When specifying equation (1), it is worth noting that we use net exports of electricity considering the specificities that imports of electricity may be destined for transit through the country. The variable $\tau_{i,j}$ is more relevant to reflect the interconnection of electricity systems between countries instead of showing the distance between them, as is the case in the standard gravity model. The econometric specificities of dealing with the variable presenting regulations in the model are presented in the next section of the paper.

As Shepherd, Doytchinova and Kravchenko (2019) note, when presented in the traditional way, at least two serious restrictions may arise in the application of the gravity model. First, by focusing only on the distance between the countries, but not on the trade restrictions such as tariffs, quotas and preferential trade agreements, an important aspect of foreign trade is missed, which could significantly affect it. That is why we include a variable in equation (1) for the regulations in the field of foreign trade in electricity. Second, the traditional gravity model does not consider changes in the relative prices of the product concerned, but only the absolute prices. In the case of electricity trade, this is a very important shortcoming given the price volatility demonstrated in 2021.

Considering the abovementioned restrictions and the current state of economics and econometric methods, the structural gravity model is more commonly based on microeconomic foundations. In our paper, we rely on the approach of building and evaluating structural gravity models of Anderson and Van Wincoop (2003). This is the so-called 'Gravity with Gravitas' model that consists of the following equations:

$$NX_{i.j} = Y_i^k + C_j^k - Y_j^k + (1 - \sigma_k)\left[\tau_{i,j} + Reg - \Pi_i^k - P_j^k\right] \quad (2)$$

$$\Pi_i^k = \sum_{j=1}^{N} \left(\frac{\tau_{i,j}^k + Reg}{P_j^k}\right)^{1-\sigma_k} \frac{C_j^k}{Y^k} \quad (2a)$$

$$P_j^k = \sum_{j=1}^{N} \left(\frac{\tau_{i,j}^k + Reg}{\Pi_i^k}\right)^{1-\sigma_k} \frac{Y_i^k}{Y^k} \quad (2b)$$

where:

i and j are used to denote the countries concerned; k is the specific sector, i.e. electricity sector;

C – the consumption of electricity in the importing country, which determines the need for electricity import;

Y^k – the generation of electricity in the region concerned, such as:

$$Y^k = \sum_{j=1}^{N} Y_j^k$$

where σ_k is the intra-sectoral elasticity of substitution;

Π_i^k reflects the fact that exports from one country to another depend on trade costs across all possible markets;

P_j^k captures the same fact as Π_i^k but as regards the imports.

Equation (2) enables us to reflect foreign trade in electricity in a more realistic way by including important variables such as its consumption and opportunities for differentiated transmission between the countries based on the provided interconnection. The interconnection in the transmission of electricity is reflected by including in our model only countries that share a common border and between which the physical transmission of electricity is possible. This is also achieved by extending the standard gravity equation with equations (2a) and (2b), which demonstrate how specifically the export of electricity depends on the trading conditions throughout the region. This is the way we overcome the specified restrictions of the traditional gravity model.

Given that our goal is to adapt the model to the electricity market in South East Europe, it is necessary to reconsider the inclusion of explicit variables for the regulations and fees for the transmission of electricity. In 2011-2019 Bulgaria was the only EU Member State to tax electricity exporters with a fee of EUR 5 /MWh (VAT excluded), in fact, a hidden duty. At the end of 2018, the Court of Justice of the European Union in Luxembourg ruled on a similar case concerning Slovakia and adopted a decision prohibiting the EU countries from imposing fees on the export of electricity generated on their territory. In 2019 the fee for transmission and access to the electricity transmission grid, paid by electricity exporters, were abolished. According to the Court of Justice of the European Union, the imposition of such fees violates the principles of the free movement of goods within the EU[7]. However, in the case of Bulgaria, such an action stimulated the exports of electricity because to be successfully realized on the foreign energy markets, the price of electricity generated in the country had to be at a competitive level even after the imposition of the hidden export fee. Currently, exporters and importers of electricity are paying administrative fees (to transmission operators, commodity exchange operators, etc.), which are in line with the EU directives. This demonstrates that the regulations in the field of electricity exports have a potential impact on the trade flows, which gives us reason to include such a variable in the model. Meanwhile, we acknowledge that it is quite difficult to capture the impact of regulation on electricity adequately given the economic differences between the countries in the region, the long period under review (1990-2019), the different initial periods of EU membership, and some of them are not yet EU members. To a large extent, this creates the expectation that the effect of regulations in the econometric assessment, which is based on a dummy variable, is unlikely to be properly accounted for.

When evaluating electricity exports, the interconnection is also an important determinant, which requires a special emphasis on the countries included in the model. Another factor that matters significantly for the electricity trade in the region are the prices formed on the energy exchanges in Bulgaria (IBEX), Greece (HENEX) and Romania (OPCOM). The Hungarian Exchange (HUPX) also has a major influence on price levels in the region and acts as a connecting link between the market areas in South-Eastern, Central and Western Europe.

In most cases, the greatest demand, and hence the higher prices, is observed in the Greek and Hungarian markets. The high prices there are not only due to the market coupling, as there has been a correlation of prices before, but mostly to the local specificities and the existence of the so-called bottlenecks. The Greek market has traditionally experienced a shortage of electricity (especially during the summer). The prices in the Hungarian market are higher compared to the Romanian market because it is a traditional importer. In recent years Hungary has emerged as an important energy hub connecting the region with the markets in Central and Western Europe. Given the interconnection provided, we include Serbia, Republic of North Macedonia, and Turkey in the model in accordance with equations (2a) and (2b). The main imports of electricity in Serbia are carried out from Hungary due to the good connection, with deficits being covered by imports from Romania and finally from

[7] More broadly this issue is discussed by Madanski, 2021.

Bulgaria. The Republic of North Macedonia is a transit country (from Serbia to Greece) and a major exporter to the Greek market.

In the Ten-year Network Development Plan of Bulgaria in 2021-2030 by the Electricity System Operator EAD (ESO EAD, 2021), for the first time, attention is paid to the influence of the electricity transmission system (EES) of Turkey in relation to electricity flows in the East-West direction (p. 16). The emphasis is on the predictions of the Turkish system operator TEİAŞ for high growth of new generating sources with a low price of electricity and the possibility of year-round export. As regards Bulgaria, the lack of investments in the construction of large sources of electricity in the electrical equivalent circuit (EEC), which are affordable 24 hours a day, also creates concerns about the Bulgarian export role on the electricity market in the region.

The abovementioned factors would be extremely important because they could increase the transit flows of electricity through the Bulgarian transmission network, turning the Bulgarian-Turkish and Bulgarian-Serbian borders into bottlenecks that would limit electricity trade. It should also be considered that when the coal plants in the Maritsa East complex are closed or reduced (due to the commitments related to the Green Deal), the transit of electricity from Turkey through Bulgaria will be greatly increased. The Turkish electricity transmission network is joined to the EU one and through its actions as a tender operator, ESO EAD offers, and it distributes and provides 50% of the available transmission capacity for the transmission of electricity in both directions between the electricity systems of Bulgaria and Turkey.

Econometric Estimation of the Model

We transform equation (2) for the purposes of econometric estimation as follows:

$$NX_t = \beta_0 + \beta_1 Y_t + \beta_2 C_t + \beta_3 Reg_t + \beta_4 Fj_t + e_t \quad (3)$$

We use the variable Fj_t to control fixed effects in relation to the other countries in the model compared to Bulgaria. The variable Reg is a dummy one with value 0 if there is no specific regulation in a specific year and 1 if such a regulation exists. Our analysis of regulations regarding the cross-border trade in the electricity markets in the region is based on official documents of the European Commission and energy agencies of the countries under review.

We estimate equation (3) through a panel data technique of fixed effects estimation, using annual data for 1990-2019 from Eurostat for Bulgaria, Romania, Serbia, Republic of North Macedonia, Greece, Turkey, and Hungary. According to Shepherd, Doytchinova and Kravchenko (2019), the most used method for the estimation of the structural gravity model is the panel data technique of fixed effects estimation. The application of this method consists in the inclusion of dummy variables for each exporter and importer in the model, which are added as explanatory variables. This allows us to adhere to the basic assumptions in the Ordinary Least Squares (OLS) model for a consistent, unbiased, and efficient estimator. A potential problem may arise because of the presence of a perfect correlation with the variables for which we have set fixed effects; therefore, in the evaluation of equation (3), we pay special attention to the variance inflation factor (VIF).

In terms of interpretation of the results, it would be more appropriate to set equation (3) in logarithmic form. However, due to the presence of negative values of the net export of electricity, the estimation is based on absolute values of the indicators. We consider that different methods may be applied to transform negative values into logarithms (i.e., to add a constant value to the data or use missing values), but since it is important to reflect whether a country is a net exporter or net importer of electricity, which can best be captured by the absolute value of net exports, we do not make such data transformations. In interpreting the results, we fully account for the fact that we have used absolute values.

Another important point of the econometric assessment is that we use data for countries of different size, economic development, and cyclical phases. This makes it necessary to find a common measure for the data to be compared. Due to these circumstances, we use data on net exports, generation, and consumption of electricity relative to the GDP of the respective countries from the IMF and the Eurostat. Let's recall that our main goal is to assess the extent to which net exports of electricity are driven by domestic generation and consumption, or other external trade factors matter much more. This would tell us whether the region's electricity trade is driven by fundamentals, or, like other commodities, one could argue for a speculative movement of electricity flows motivated by factors such as prices. This indirectly addresses the question of whether national electricity supplies in the region would be affected in times of strong external demand, sacrificing national energy security at the expense of benefits from foreign trade.

The first step is to estimate the correlation between the stationary variables, which is shown in the matrix in Table 1.

Table 1

Correlation matrix of variables used

Variable	Net exports	Generation	Consumption	Regulation
Net export	1	0.328	-0.022	-0.042
Generation	0.328	1	0.888	-0.078
Consumption	-0.022	0.888	1	-0.044
Regulation	-0.042	-0.078	-0.044	1

The data shows a low positive correlation between net electricity net exports and generation, and almost a zero correlation with electricity consumption. This is probably due to the high levels of electricity transit in the region. In another aspect, we can argue that the export orientation of the electricity sector is not a factor that affects the national energy security. There is a high positive correlation between electricity consumption and generation. This is indicative of the still weak interconnection in the region and of the development of foreign trade in electricity, in which the liberalization processes are still expected to intensify the market. Regarding regulations, as expected, there is no significant effect given their limited application for the period under review and all the restrictions we face to incorporate them in the model.

Next, we check the data stationarity. Given the larger sample size (203 observations) and data specificities, we apply the Phillips-Perron (PP) unit root test. The results show that in the absolute values form, only the net exports are a stationary variable, while in the first differences, all variables are stationary. The results are summarized in Table 2.

Table 2

Result of Phillips-Perron (PP) unit root test of the variables

	Level Form			First Difference		
Variable	Tau (Observed value)	Tau (Critical value)	p-value (one-tailed)	Tau (Observed value)	Tau (Critical value)	p-value (one-tailed)
Net exports	-3.581	-3.432	0.034	-13.504	-3.432	< 0,0001
Generation	-2.754	-3.432	0.216	-8.398	-3.432	< 0,0001
Consumption	-2.866	-3.432	0.176	-6.944	-3.432	< 0,0001

Hypothesis testing

H0: There is a unit root for the series.

Ha: There is no unit root for the series. The series is stationary.

Decision rule: If the computed p-value is lower than the significance level $\alpha = 0.05$, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.

The econometric estimation employing a panel data technique of fixed effects estimation is summarized in Table 3.

Table 3

Econometric results

Variable	Coefficient	Std. Error	t-value	Pr(>|t|)	VIF
Generation	0.690	0.025	27.180	<0.0001	5.823
Consumption	-0.858	0.029	-29.131	<0.0001	5.321
Regulation	0.267	10.735	0.025	0.980	3.452

R-squared: 0.904
F-statistics: 605.261
Breusch-Pagan test p-value: 0.083
Adjusted R-squared: 0.899
Durbin-Watson test: 1.864
White test p-value: 0.038

The results show that the net exports of electricity in South East Europe would increase by 0.690 units if the generation of electricity increased by 1 unit, as well as that the net exports of electricity would decrease by 0.858 units if the consumption of electricity increased by 1 unit. As the correlation matrix shows, the effect of regulations is statistically insignificant, and the sign of the variables under consideration, which sets the direction of the relationship between them, is the expected one.

From a statistical point of view, the three variables included (generation, consumption, and regulations) explain about 90% of the variance in net exports of electricity, which is indicative of their fundamental nature and strong effects on the cross-border trade in electricity. The Variance Inflation Factor test for multicollinearity shows that the values obtained for all variables are far below 10, and the Durbin-Watson autocorrelation test has a value of 1.864, showing that autocorrelation between the residuals is not greater than 0. The probability values of the Breusch-Pagan test and the White test for heteroskedasticity allow us to accept the null hypothesis of homoskedasticity.

When analyzing the results, one can reason on the trends they show rather than on their values. This is because we use a panel model where the panel data levels the playing field and given the dummy variables for the regulations. It is noteworthy, however, that domestic consumption of electricity is a much stronger factor than the generation, when considering foreign trade in electricity. This allows us to argue that the construction of power capacity in the countries considered is much more oriented towards the domestic market than towards the regional market, which is also shown by the underdeveloped interconnection between them. This is a serious obstacle to the liberalization on the electricity market in the region, which would also affect its integration into pan-European market structures. In purely domestic terms, this creates the conditions for maintaining higher prices and, consequently, negatively affects economic development.

Conclusion

The positive dependence of net electricity exports on generation in the region of South East Europe is not surprising given the fundamental relationships between the two. The high exports of electricity, in which mainly foreign companies from the region are involved, encourages investments in generation and employment. Hence, it creates preconditions for even greater growth of electricity generation, which becomes more expensive in view of all imposed initiatives to limit environmental pollution. Thus, a foreign trade transmission of electricity, which relies mainly on local generation, emerges, and combined with low interconnection, leads to higher electricity prices. These processes show the need for greater intensification of the interconnection and point to the serious challenges to the expansion of electricity transit and liberalization on electricity markets. The strong negative relationship between net electricity exports and consumption we find in the region implies a strong seasonal dependence of net exports and volatility relative to consumption, and hence it has a direct price effect. This shows that electricity exports are an additional factor rather than a basis for the development of the electricity market in South East Europe, which has an impact on both the success of market liberalization policies and the dynamics and high volatility of prices. The strong and negative relationship between net electricity exports and consumption reaffirms the essential role of the interconnection in the development of the electricity trading market in South East Europe, which the purely regulatory initiatives for regional integration and harmonization of the regulatory frameworks cannot replace.

To comprehensively evaluate the opportunities for clean exports of electricity from the countries in South-Eastern Europe, Turkey’s influence on the region must also be considered. The expected growth of production capacities with year-round export opportunities in the largest regional economy will strengthen the transit component of net exports in South-Eastern Europe and will negatively affect the possibilities of other countries to carry out their own exports, especially given all the restrictions under the EU Green Deal on coal production. The development of electricity capacities in Turkey would have the most direct effect on Bulgaria, which can benefit from the transit flows of electricity through the national transmission network in the east-west direction and thus compensate for the possible closure of the generating capacities of the Maritsa-East complex by increasing dependence on electricity production in Turkey. Turkey’s position demonstrates that the potential for foreign trade in electricity directly depends on the available NPPs, through which not only the foreign trade position can be preserved but also the coverage of the domestic electricity needs can be guaranteed, based on the example of Bulgaria. In this way, the market liberalization and the introduction of similar regulatory practices would have a real impact and would mitigate the volatility of prices in electricity markets, which also significantly affects the macroeconomic stability at a national level.

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