EU DECARBONISATION: DO EU ELECTRICITY COSTS HARM EXPORT COMPETITIVENESS?

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Abstract

The EU has become a leading protagonist of decarbonisation in the era of challenging international competitiveness. This research aims to investigate a relationship between energy costs pushed by decarbonisation (case of electricity) and the export competitiveness of EU countries. Within panel regression, the authors used unit energy costs (UEC) for electricity and analysed export competitiveness via domestic value added in gross export from the TiVA database. The research proved the negative effect of increasing unit energy costs for electricity on export competitiveness, but only at the entire industry level. The even stronger negative effect of increasing energy costs was found among EU13 countries (new members and industry-based countries). The original and most important findings bring UEC data for the EU countries, prove different effects of decarbonisation on export competitiveness within the EU27, and investigate selected decarbonisation effects on energy-intensive industries. The results related to the potentially harmful and diversified effects of decarbonisation commitments on export competitiveness are essential for further "green" reforms policies of the EU.

Keywords: Decarbonisation, electricity prices, export competitiveness, energy intensive industries, energy costs.

JEL Classification: D24, C53, O13, Q43.

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Introduction

The environmental ambitions of the EC were strengthened by the new president, U. von der Leyen, who defined the fight against climate change as a supreme priority. The European Green Deal was approved in 2020, and the “Fit for 55” package was publicly introduced in July 2021. The Russian invasion of Ukraine and the subsequent energy crisis intensified the need for a greener, self-sufficient Europe. The topic of energy and industry decarbonisation thus becomes a key topic for European industry and industrial exports, which the EU has dominated for decades. Decarbonisation affects the new EU Member States (CEE) more, since their GDP creation strongly depends on industrial production.

The negative externalities of decarbonisation are noticeable primarily for industrial production and export companies. According to several authors, energy costs become a critical determinant of the competitiveness of the selected EU industrial exporters (Kaltenegger et al., 2017; Baláž et al., 2020; Černá et al., 2022; Faiella and Mistretta, 2022) after unit labour costs (Ecofys/Fraunhofer, 2016; Faiella and Mistretta, 2020), especially relevant for energy intensive industries in the CEE region (Baláž and Bayer, 2019). Porter (1991) has been dealing with this phenomenon since the 1990s. Based on research in American companies, he formulated the so-called Porter’s hypothesis, which assumes that strict environmental regulation causes restrictions or increases costs, and this forces companies to introduce innovative solutions to reduce energy consumption or increase productivity. Ultimately, these local restrictions (regulation) bring companies higher international competitiveness (export competitiveness) caused by technological innovations, the introduction of cleaner production technologies, or more efficient production processes.

One of the most fundamental manifestations of decarbonisation is energy costs. Several analysts and economists criticised the EU’s decarbonisation policy and adopted the concept of “Energiewende” in the European energy sector as being primarily responsible for the decline in exports, especially the industrial export performance of the EU 27 for other years (Baláž and Bayer, 2019). Electricity prices are typical areas of energy and industry where the megatrend of decarbonisation challenges. Many EU countries implement the stimulation of the use of renewable resources, as a pillar of decarbonisation, through feed-in tariffs. Besides emission allowances, these environmental tariffs increase electricity prices, which play a key role in the price competitiveness of producers on domestic, but especially foreign markets. Transferring this financial burden to companies can be dangerous (comparing households) due to the loss of cost competitiveness. Subsequently, there is a high risk of a phenomenon in international business that economists refer to as the “pollution haven hypothesis”, i.e., migration of EU industrial producers to countries with a lower level of environmental regulation and, thus, a decrease in export performance.

Thus, an inappropriately implemented RES directive and other decarbonisation measures in an EU Member State can thus contribute to the deterioration of the exports of more energy-intensive industrial exporters through higher electricity prices. A typical example is the closure of several energy-intensive industrial producers in 2022, especially in CEE countries. In previous research, only a few authors and economic researchers have addressed the issue of the impact of decarbonisation on energy costs. The impact of decarbonisation directly on electricity prices as a competitiveness factor is rare. Another trend in CEE countries is the research of GVCs’ participation and the effort to increase the domestic added value of gross exports as much as possible. Concerning the acute need for economic policy in CEE countries, the presented contribution examines the impact of rising electricity prices (as a manifestation of decarbonisation) on the competitiveness of exports, exports explicitly expressed through value-added as proposed by TiVA (OECD, 2021). We consider it necessary to identify whether EU industrial exports are undergoing a "crowding out" phase in the international business environment due to higher electricity prices. To answer this question engaging quantitative research methods, it is possible to contribute to the improvement of policy design in industrially-oriented EU countries, primarily CEE countries. The research question is: *"To what extent do energy prices (electricity) affect the exported value of the EU industry?"*

In the first part of the article, we provide a literature review and our own findings in the area of the impact of decarbonisation (environmental regulation of energy prices) on international competitiveness and export performance. Secondly, we examine the causal nexus between decarbonised (higher) electricity prices and their impact on export performance.

To answer the research question, we chose the panel regression method for examining the impact of electricity prices through the parameter UEC_{EE} (unit energy costs in the case of electricity derived from previous authors like Faiella and Mistretta, 2022) and its impact on exports, specifically domestic value-added in gross exports. This effect is examined for the EU Member States, respectively, segments of the EU27 countries (original EU15 vs. new, more industrially-oriented countries). The findings of the panel regression could be helpful for further decarbonisation in the EU as a way to reduce CO_2 emissions and the import of fossil resources from the Russian Federation or other third countries. Research in this area can help form new energy and industrial policies by assessing the sensitivity of the introduced measures with a potential effect on the vulnerability of industrial exporters, especially those from CEE countries.

1. Literature review. Decarbonisation and competitiveness of industrial exporters

Given the stated decarbonisation measures, European industrial producers naturally lobbied for their gradual implementation and preservation of cost competitiveness in comparison to foreign producers who did not have to implement such strict regulations (emission allowances, special tariffs, environmental standards, etc.).

Research on the *causality between electricity prices and cost competitiveness* was not frequent until 2010, and renowned studies (Enevoldsen et al., 2007) identified no significant negative impact of rising energy costs on the competitiveness of companies. Until 2010, research on the relationship between electricity consumption and economic growth or cost competitiveness (Narayan and Prasad, 2008; Payne, 2010; and Ozturk, 2010; Acaravci and Ozturk, 2012) dominated. The directive on renewable energy sources, which began to significantly increase electricity prices through feed-in tariffs and the collection of fees for decarbonisation measures (production resources), the first analysis of the impacts of these "green" measures began to appear (since 2010). The studies examined the *impact of rigid EU energy and environmental regulations on competitiveness* (mainly export).

The absence of this topic in the research of economists from the CEE regions can also be attributed to the fact the production of electricity was exclusively in the hands of state monopolies with an absent market and competitive environment (Pîrvu and Bădîrcea, 2013). The second separate issue in connection with the transformation of the energy consumption of the EU and especially the new Member States from the CEE region is the phenomenon of improving energy efficiency, which has a positive effect on the unit energy costs of these countries. For instance, Yu et al. (2017) revealed that the reduction in final energy consumption in most EU countries before and after 2008 can be related to the decline in energy intensities within end-user sectors.

Even since 2010, a minimum of specific impact studies have been published in this area. The report on the competitiveness of industry in the EU (European Parliament, 2016) was the first major study to examine the possible impacts of decarbonisation on energy costs and the competitiveness of European industrial producers. At the same time, mainstream reports began to state (IEA, 2014) that the EU has energy costs at a significantly higher level than the largest competitors in the US, China, or Japan. In 2014, the Oxford Institute for Energy Studies published a relevant study by D. Buchan (OIES, 2014), which states that the EU has always had higher energy costs than the US. Nevertheless, the EU achieved a long-term surplus in foreign trade in goods. However, it demonstrably mentions the possible harmful effects of an intensified fight against climate change in the EU on its exporters and, mentioned "carbon tariffs" as a possible solution.

The OECD published a study examining the impact of electricity prices on German competitiveness in 2015 (Flues-Lutz, 2015), concluding that there was no significant impact of rising electricity prices on the competitiveness of German exports, business turnover, added value, investment or employment. Another relevant analysis by the EC was a DG Energy study (Ecofys/Fraunhofer, 2016). In the case of electricity and gas prices, it also examined the profitability of industrial companies in energy-intensive industries and identified specific industries most determined by the rising costs of electricity and gas (cement production, paper industry, iron, and steel). This study indicated that the EU's generated added value on the cost of electricity consumed was incomparably lower than that of the PRC but higher than that of the US or Japan in most industries. However, the authors (Ecofys/Fraunhofer, 2016) consider commodity products the most threatened export, which face more intense competitive pressure.

Significant conclusions on energy costs in the EU and industrial competitiveness were heard on the floors of EU institutions during a public hearing on the economic consequences of RES (European Parliament, 2016). They pointed out that electricity prices across the EU are very heterogeneous, and the effects of decarbonised energies may be differentiated in the EU Member States. Lindén (2017) used the unit energy cost (UEC) methodology, and he identified that the European industry did not suffer in terms of competitiveness due to the accelerating decarbonisation, and companies managed rising energy prices through progress in the field of energy efficiency. However, the study showed a smaller success rate for absorbed price shocks in the chemical and metalworking industries. The differentiation of impacts can be considered a significant shift in impact research. This study finds that Bulgaria, Cyprus, Belgium, Slovakia, and Finland are more negatively impacted countries (Lindén, 2017) by the decarbonisation efforts.

Many economists consider the publication by Dechezlepretre and Sato (2017) to be a starting point, and frequently cited a study on the impact of environmental regulation on competitiveness. The authors (Dechezlepretre-Sato, 2017) tested the causality between the strictness of energy regulation and its impact on the company performance parameters. They based the study on the original conclusions of the renowned work by Jaffe and Palmer (1997), confirming the so-called Porter's hypothesis. The authors not only did not confirm the hypothesis of migration of companies from within the EU, but also identified a neutral to the slightly positive impact of these restrictions on the performance of European companies.

They justify this primarily by the increase in innovations, in which companies are forced to invest in more productive technologies. According to their conclusions, companies in the international environment react more intensively to other factors: transport costs, the size of the demand, the quality of the domestic workforce, the availability of mineral raw materials, capital costs, etc. (Dechezlepretre-Sato, 2017). Another study by Ecofys/Frauenhofer (2016) indicated specific energy-intensive industries that are losing competitiveness. A critical study was the analysis of the French Council for Economic Analysis, headed by the French economist Dominique Bureau (Bureau et al., 2013), on the connection between the currently high electricity prices and the competitiveness of the industry. The authors identify the loss of export competitiveness of French companies and attribute part of this problem to the rising energy costs. Immunity to such price shocks is secured by companies that achieve Porter's effect through "green competitiveness", i.e., can acquire the "first-mover" advantage of using innovative technologies.

A territorial study investigating *rising energy costs due to environmental measures* was the research of prominent Indian economists S. Kumar and P. Prabhakar (2020). They demonstrated a statistically insignificant effect of rising energy costs on the export performance of the Indian economy. Specifically, a 10% increase in relative energy prices harms export competitiveness with varying intensity: on average, it is only about 1%; for the export of chemical industry products, 0.9%; for non-ferrous metals, 1.4%, and generally, above-average values in the field of energy demanding industrial exporters. The EC's expert analysis of the 2019 vision (European Commission, 2019) emphasises the need for the decarbonisation of EU Member States based on the growing import of energy carriers from third countries. In its final recommendations, the author emphasises the need to protect vulnerable entities (including industry) so that they are not internationally disadvantaged (European Commission, 2019).

The key study by Faiella and Mistretta (2020 and 2022) helps to measure the effects on export competitiveness of rising energy prices caused by decarbonisation. The most important finding from the gravity model (panel regression with a fixed effect) was not only the confirmation of causality to the negative decarbonisation impact but also its concrete quantification: a 1% increase in unit energy costs (cumulative electricity and gas) causes a 1.2% decrease in the EU gross export. Another important conclusion claims that rising electricity prices under the influence of decarbonisation are more intense in the Member States of the eurozone (Faiella and Mistretta, 2020; Faiella and Mistretta, 2022).

More recent studies include Baláž and Bayer (2019), who evaluate the impact of rising electricity prices on production costs and conclude that the competitiveness of companies from the EU has been permanently decreasing. The latest studies in CEE countries emphasise the appropriateness and structure of the chosen policies and instruments for achieving carbon neutrality regarding the goals of the European Union Green Deal (Topor et al., 2022). Zabojnik (2020) confirmed the decreasing export competitiveness of the Slovak industrial exporters under the pressure of higher electricity prices impacted by RES fees and stressed the vital role of R&D investment. Yu et al. (2017) found that the impact is more substantial in state-owned enterprises and small and medium enterprises. Again, using the example of energy-intensive industries in the PRC, Zheng, Wu and He (2021) demonstrated that the use of dynamic prices of peak electricity on the selective energy market (differential electricity pricing) helps more efficient use of electricity, and in a short time (one year) companies invest in energy-saving technologies.

In the most recent studies, Paul and Dhiman (2021) show that export competitiveness has been studied in both manufacturing and service industries, like metals, chemicals, general and electrical machinery, transportation equipment, etc., in developed and developing countries. As for how decarbonisation efforts affect competitiveness, Venmans, Ellis and Nachtigall (2020) found that carbon pricing or energy prices did not have any significant effects on net imports, FDI flows, sales, value-added, employment, margins, or innovation activity. However, the most recent authors agree that environmental regulation policies are needed to protect the environment without hurting the manufacturing industry's ability to compete internationally.

Dragomir's (2022) results show that decarbonisation, scientific activities, and enough funding significantly affect the economic performance of the selected EU countries. The critical effects of using renewable energy are emphasised, which supports the idea that the energy transition is good for competitiveness. Analysing the same exogenous factors, Nițescu and Murgu (2022) confirmed the significant influence of renewable energy sources on the economic performance of the selected EU countries, analysed in terms of exports of goods and services. However, the results differ from country to country in this study. In this regard, Popa et al. (2022) emphasise the essential role of the country's institutional factor, which should ensure proper regulation, effective enforcement mechanisms, and financial incentives that promote the use of renewable energy.

Considering other studies, such as the European Commission's (2019) or Faiella and Mistretta's (2022), appropriate decarbonisation policy design seems particularly important for the CEE countries, mainly those of the eurozone. Focusing on the V4 region, Myszczyszyn and Supron (2021) consider decarbonisation and the region's competitiveness to be challenging, as the V4 governments are largely dependent on energy from non-renewable resources. Addressing the impact of recent energy price shocks within the EU, Jakob (2022) concludes that ambitious climate policies seem more likely to flourish in an open-world trading system that provides sufficient flexibility for individual countries to adopt nationally appropriate climate policies. The most relevant result related to our research question was brought about by the study by Faiella and Mistreta (2022). This states that increased UECs reduce bilateral exports, while euro area countries show the most prominent adverse effects.

To sum up, the most recent literature has brought significant and unique research investigating energy costs or direct electricity price dynamics' impact on export competitiveness. Without a doubt, the EU has been a leader in decarbonisation efforts globally, and many countries have financed new renewable sources via electricity bills for industrial producers (primarily via feed-in tariffs). Some works proved statistically significant causality between relatively increasing energy (electricity) prices at the general level or at least in some country/industry groups (Faiella and Mistretta, 2020; Faiella and Mistretta, 2022; Bureau et al., 2013; Baláž and Bayer, 2019; Kumar and Prabhakar, 2020) and export competitiveness; other works deny the impact of decarbonisation on increasing electricity prices and lower export competitiveness (Flues-Lutz, 2015*;* Lindén, 2017*;* Dechezlepretre and Sato, 2017*;* Venmans, Ellis and Nachtigall, 2020). Among these studies, a considerable literature gap exists between decarbonised energy (electricity prices) and its impact on exports expressed via value-added. The need for this research is supported by the recent studies highlighting the importance of the GVCs phenomenon (Kaltenegger, 2017; Černá et al., 2022), especially within EU countries. Moreover, due to the different results of the studies, the effects have to be examined at the whole industry and a sub-industry level due to possible negative aspects of the common EU decarbonisation policy.

2. Data and methodology

The presented contribution aims to identify the causal nexus between the dynamics of unit energy costs of electricity across EU countries and their industrial exports (added value in exports) at the overall level and for individual industries. The investigation of unit energy costs and their dynamics (year-on-year change) is justified in determining the effect (consumed amount of energy or increase in energy costs) of an increase or decrease in UEC in the field of electricity. Due to the liberalisation of the European electricity market, market coupling (Ruggiero et al., 2015) and relatively low spreads in electricity prices between individual states, network fees, in particular, can be considered a significant factor in the increase, especially in the area of decarbonisation, the feed-in tariff, which it largely explains the price differences for final electricity consumers (at the level of industrial producers) as proposed by Faiella and Mistretta (2020) and Zabojnik (2020).

The field of methodological approaches to evaluating competitiveness differs widely among authors, starting with evaluating companies (Krugman, 1994) vs evaluating economies - countries (Porter, 1990). However, in connection with energy policy and a considerable degree of regulation at the EU level, the conditions are generally the same for all companies within one regulatory territory (national economies). For this reason, we evaluate countries and the impact of energy policy on electricity prices and the value of UEC_{EE} at the state level.

Several economists point to the importance of GVCs in international trade and the need for the involvement of national economies in GVCs in order to maximise domestic added value and benefits resulting from involvement in international trade. In this context, the export dynamics (year-on-year change) will be evaluated at the level of exports reported through their value-added (TiVA) in the form of the EXGR_DVA parameter from the OECD database (2021). Subsequently, panel regression will evaluate the causality of UEC_{EE} and interannual changes in EXGR_DVA for individual states, groups of states, industry in general, and selected industries.

This article stresses the role of increasing energy costs as an impact of sustainability and its position within cost competitiveness and perspective export competitiveness of the EU Member States' enterprises, as initially proposed by Faiella and Mistretta (2020). The primary data for these indicators were drawn from the EUROSTAT (2022) database for value-added, the National Energy Balances database (EUROSTAT, 2022: NRG_PC_205_H and NRG_BAL_C) for electricity and gas consumption, and the Eurostat database (2022: NAMA_10) for electricity and gas prices. Electricity prices in the whole work are prices including network and distribution fees in € / MWh without deductible and refundable taxes (excluding VAT) applying median consumption.

Unit energy costs (UECs) have been a new concept that is part of the methodology of primary studies for the European Commission and academic research and research for industry unions for a relatively short period. It is based on the similar methodological concept of unit labour costs, but in energy. This concept was first described and used for research by Enevoldsen et al. (2007) to examine the effect of energy taxes on increasing actual energy costs on the competitiveness of industrial exports. The authors examined the increase or decrease in competitiveness through a value-added output change. By confirming or refuting this causality, the authors examined the impact of electricity costs for industrial exporters on industrial export competitiveness.

The general formula for calculating the unit energy costs, (UEC and UEC_{EE}), at the general level and particularly for the electricity is:

$$UEC = \frac{EC}{VA} \quad (1)$$

and

$$UEC_{EE} = \frac{EC_{EE}}{VA}, \quad (2)$$

where:

EC - represents the energy costs in relation to the whole industry sector;
VA - represents the added value of the whole industry sector;
EC_{EE} - represents the energy costs within electricity in relation to the whole industry sector.

The formula quantifies the contribution of energy costs (EC) to value-added (VA) in percentage terms (Faiella and Mistretta, 2020). The advantage of the application is the possibility of its use if data are available on the total energy consumption or the consumption of a specific energy carrier at the level of the EU or the state economy. On the negative side of many studies examining the effects of rising energy prices and the success rates of their elimination, they have generalised the conclusions and recommendations as they examined the EU as a whole (several European Commission studies). The UEC indicator makes it possible to examine the impact on the EU as a whole, but also on the Member States, the industry as a whole, and individual industries. This is possible through the decomposition into individual components and the main determinants of the dynamics of the year-on-year change in the UEC parameter. The specific calculation of unit energy costs is as follows (Enevoldsen et al., 2007; Lindén et al., 2017; Faiella and Mistretta, 2020):

$$UEC_{EUt} = \frac{\sum_{sie} K_{siet}(P_{set}+\tau_{set})}{\sum_{si} VA_{sit}} = \sum_{si} \frac{VA_{st}}{\sum_{s} VA_{st}} \frac{VA_{sit}}{\sum_{i} VA_{sit}} \frac{\sum_{e} K_{siet}(P_{set}+\tau_{set})}{VA_{sit}} = \sum_{s} z_{st} \sum_{i} q_{sit}\, UEC_{sit}\ , \quad (3)$$

where*:*

$\boldsymbol{K_{siet}}$ - represents the quantity of the energy source *e* used at time *t* in industry *i* of country *s*, and *p* as the price and τ as the tax and levies (as Faiella and Mistretta, 2022)

$\boldsymbol{q_{sit}} = \frac{\boldsymbol{VA_{sit}}}{\sum_{i} \boldsymbol{VA_{sit}}}$ - represents the share of sector *"I"* in country *"*s*"* and time *"*t*"* in relation to the whole industry sector, and

$\boldsymbol{z_{st}} = \frac{\boldsymbol{VA_{st}}}{\sum_{s} \boldsymbol{VA_{st}}}$ - represents the contribution of the industry of the country "s" with respect to the total industry at EU level.

The aim of the contribution, using this methodology, is to quantify the impacts of decarbonisation on electricity costs, which is most sensitive for industry, primarily through feed-in tariffs. The impacts will be examined on the example of the EU (a typical representative of environmental regulation through the feed-in tariff) to analyse the amount and dynamics of UEC in the case of electricity prices (UEC_{EE}). In general, we work with the null hypothesis that the impact of electricity prices is not statistically significantly dependent on the value added exported by individual EU countries.

Most research taken into account within the literature review used datasets based on conventional gross exports statistics. However, these statistics do not reflect a possibility that the exports of the given sector may remain at the original level; however, inputs in the form of imported commodities and semi-finished products may, over time, contain a higher level of imported added value from abroad due to the displacement of more energy-intensive parts of value chains outside the EU. This could increase re-exportation of energy-intensive intermediates and decrease domestic added value. This fact results in the expected transformation of GVCs to the disadvantage of more energy-intensive countries. For this reason, it is correct to examine the added value of the export itself and not only the gross export. (Černá et al., 2022).

For the panel regression, the data in this area were drawn from the OECD database (2021) in TiVA format, as EXGR_DVA. For research purposes, commodity groups from the OECD database (2021) were adopted to be compatible with the NACE division of industries in the field of statistical data for energy, which Eurostat (2022) used.

Regarding the *research methodology*, the objective of our paper is to verify and quantify the effect of electricity unit energy costs (UEC_{EE} or UEC_EE) on the exported value added of the European Union countries in selected sectors from 2008 to 2018. We utilised quantitative methods, specifically regression analysis of panel data with fixed and time effects. Fixed-time effects have the advantage of including unobserved phenomena in the model specification (Fišera, 2022; Hsiao, 2014). The modified economic panel data equation with fixed effects has the following form: where EXGR_VA means natural logarithm of exported value added from the OECD (2021) TiVA database, UEC_EE (determined from Eurostat, 2022) as mentioned above is the natural logarithm of electricity unit energy cost, GDP_ppempl means labour productivity expressed as gross domestic product per person employed (as proposed by ILO, 2021), and R & D_sh is the share of science and research expenditures in gross domestic product (WBG, 2022). U represents a random error, αi and λt signify fixed and time effects, respectively (Lukáčiková, 2013; Lu and Su, 2020):

$$\boldsymbol{EXGR\_VA_{i,t,s}} = \alpha_i + \lambda_t + \beta_1 l\_UEC\_EE_{i,t,s} + \beta_2 l\_GDP\_ppempl_{i,t} + \beta_3 RandD\_sh_{i,t} + u_{i,t,s} \quad (4)$$

We adjusted the variables using a logarithmic transformation, except for R&D expenditures, which are expressed as percentages. We also logarithmised UEC_EE, which is expressed in shares. The advantage is that we thus eliminated zero values in the file. The variables' parameters were estimated using the software GRETL (Cottrell and Lucchetti, 2021), and the presence of a collinearity error in the pool model was examined using the Variance Inflation Factors test (Adkins et al., 2015). Due to the possibility of heteroskedasticity and autocorrelation, we employed a robust standard error (HAC). The risk of a short-time series being non-stationary is low, which is an advantage of our approach (Frensch, Hanousek and Kočenda, 2013). We can assess the individual parameters' estimates of the significance of the variables by the number of displayed asterisks (Lukáčik, Lukáčiková and Szomolányi, 2011): *** - 99 %; ** - 95 %, and * - 90 % probability of the null hypothesis rejecting about the insignificance of the variable estimate. In the case of non-lagged models, we evaluated the years 2008-2018; however, if we lagged our independent variables, we assessed the years 2008-2018 as the dependent variable, but the independent variables were for the period 2007-2017. If we tightly limited the database to 2008 to 2018, the estimates would vary by a constant. The missing values may represent observations that were not included in the source data or zero-valued observations that were omitted during logarithmic processing. In this instance, we rely on the Gretl software procedure that automatically omits any missing variables (Cottrell and Lucchetti, 2021).

3. Results and discussions

The first fundamental findings were already brought by the analysis of UEC_{EE} across the EU Member States and for the EU28 (current 27 members + UK) as a unit, respectively. The average value of this parameter reaches 0.031 for the EU, which means that electricity costs share 3.1% of the EU-generated value. A significantly lower UEC_{EE} can be clearly identified in the industrial production of the Eurozone countries or particularly countries such as Denmark (1.6%), Ireland (1.0%), and the Netherlands (2.7%), which can be explained by innovative and energy-saving production capacities, high-tech production in industry, but also the tax domicile of many critical industrial producers from the EU. Paradoxically, industrially-oriented EU economies such as Slovakia (6.1%), Bulgaria (6.0%), and Slovenia (4.2%) achieve a very high value of UEC_{EE}. Following the methodology, a panel regression was processed with the mentioned variables. Results are shown in table no. 1.

The presented results show no statistically significant impact of unit energy costs in electricity on the total EU exports. On the other hand, the impact of labour productivity per employee was demonstrated at a significant statistical level, which is the expected result (1.50) following previous studies. Thus, we rejected the null hypothesis about the insignificance of the labour productivity variable estimate; with an increase in the value of the variable by 1%, we expect an increase in exported value added of 1.50%. An identical analysis at the industry-only level yielded interesting findings. In this case, the unit energy costs in electricity at the level of all the EU Member States (-0.11) have a statistically significant influence on the exported added value. A similar finding, but at a lower level of statistical significance (-0.07), was identified with a variable lagged by one year (costs of electricity applied in the following year due to fixed prices), with the labour productivity parameter again significant. The expected result is a significantly higher sensitivity of the added value of exports in the case of the industry-based countries of the EU 13 (primarily the CEE region). In this case, without the lagged dependent variable, an even more statistically significant dependence of the exported added value on the unit energy costs in electricity was demonstrated: while at the general export level, it does not have a statistically significant effect, in the case of industry the results indicate a strong statistical significance, considerably higher than that at the EU28 level. Paradoxically, this dependence was not confirmed at a significant level in the case of energy-intensive industries. In the case of specific energy-intensive industries, a statistically significant dependence of export performance on UEC_{EE} was demonstrated only at the level of basic metals production (-0.11) and in all EU states.

Table no. 1. Panel regression results

Dependent variable: l_EXGR_DVA	**const**	**l_UEC_EE**	**l_GDP_ppempl**	**RandD_sh**
DTOTAL	-6.04***	-0.05	1.50***	0.01
EU_non-intensive + energy intensive sectors (industry total)	-8.33**	-0.11***	1.32***	0.04
EU13_ non-intensive + energy intensive sectors (industry total)	-11.48**	-0.14***	1.56***	-0.04
EU13 DTOTAL	-5.21*	-0.02	1.38***	-0.06

Dependent variable: l_EXGR_DVA	const	l_UEC_EE	l_GDP_ppempl	RandD_sh
EU_intensive	-10.94***	-0.04	1.58***	0.02
EU13_intensive	-10.94**	-0.07*	1.61***	0.04
EU_Manufacturing	-9.57**	-0.10	1.71***	0.07
EU13_Manufacturing	-5.45	-0.01	1.32***	-0.03
Basic metals	-5.52	-0.11**	1.17***	0.04
Chemical products	2.44	-0.05	0.45	0.03
Paper and celulose	-19.83**	0.10	2.35***	0.13*

const	l_UEC_EE_1	l_GDP_ppempl_1	RandD_sh_1	n	Adj. R2
-3.82*	-0.02	1.32***	-0.01	276	0.77/0.79
-4.18	-0.07*	0.97***	0.04	2247	0.17/0.15
-4.64	-0.08	0.95*	0.00	1062	0.16/0.14
-1.49	0.00	1.06***	-0.05	129	0.81/0.84
-7.99**	0.00	1.33***	0.02	1231	0.25/0.26
-10.52***	-0.02	1.59***	0.06	649	0.43/0.40
-6.86	-0.03	1.50***	0.04	274	0.65/0.66
-2.40	0.09	1.07***	0.01	129	0.68/0.74
-5.77	-0.10*	1.20***	0.07	253	0.48/0.46
3.54	0.03	0.38	0	230	0.37/0.35
-17.01***	0.06	2.10***	0.14**	246	0.38/0.42

Notes: Column n contains the number of observations for the period 2008-2018; EU represents all Member States and the United Kingdom

Standard error = heteroskedasticity and autocorrelation corrected (HAC); Country-sector effects: Yes; Time effects: Yes

_1 = time lag of independent variables (t-1)

EU 13 cover countries with higher share of industry on average, mostly CEE coutries: Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Bulgaria, Croatia, Cyprus, Malta, Romania

Source: Processed by author

Researching the impact of electricity bills, which are significantly higher for the EU than for producers in the US, PRC or Japan, is an extremely topical issue in the field of export competitiveness. This issue dominated expert discussions prior to the proposal of carbon tariffs by the EC. Several industrial giants pointed to the possible "exodus" of industrial production from the EU and the replacement of environmentally-friendly domestic industrial production by importing goods from producers of non-EU origin. Critics pointed out that imports from countries such as the PRC, the Russian Federation, Indonesia, Vietnam, etc., generate the opposite effect – the EU will import goods whose carbon footprint is significantly higher than that of EU industrial producers, who are burdened by stringent environmental regulation and high electricity prices due to decarbonisation. The examination of this dependence is, therefore, crucial for the efficient policy designing of the European Commission.

This issue is exacerbated by the sharp loss of the EU's competitiveness in foreign markets, as the share of the EU 27 countries is today at the level of approximately 16% of world exports, while in 1980, the share of only the EU 15 in world exports was approximately 37% (ITC, 2022). It indicates a sharp loss of the EU's position in world trade, and energy costs may be a fundamental factor in restoring competitiveness growth or its permanent decline.

According to Garelli (2006), governments significantly determine the competitiveness of domestic producers through the formation of the institutional environment (elements of the business environment), especially during periods of crisis. This conclusion is particularly crucial for the relationship between environmental policy and energy policy in relation to export stimulation. The degree of regulatory involvement in energy prices determines the production costs of domestic companies. Based on the concept of "national competitiveness", it is relevant to examine the impact of energy policy (targets set at the EU level and implementation tools at the national level) on the competitiveness of industrial producers.

Several findings from the panel regression are expected and confirm the impact of UEC in electricity on exported value-added. However, several of the authors' model results show an overestimated importance of electricity costs when examining the export performance of industrial producers in the EU. This correlates with the previous findings such as Dechezlepretre-Sato (2017), Flues-Lutz (2015), Lindén (2017), and Venmans, Ellis and Nachtigall (2020). We consider our analysis's fundamental contribution to examining the impact of potentially higher energy costs due to decarbonisation not only on gross exports but directly on added value in exports, which better explains the effects on EU competitiveness and standard of living in the EU Member States. Therefore, this finding better fills the gap in the research addressing exported value-added directly, which could help the proper policy design mainly in the case of smaller, opened economies (Czechia, Slovakia, Hungary, Slovenia, and also Baltic countries).

Concerning the possible impact of UEC_{EE} on the total added value in EU exports, a statistically insignificant impact can be noted. We explain this result due to a large part of EU countries' exports flows to the markets of other EU Member States as a part of intra-trade. Rigid environmental policy is applied to all Member States, and the potential disadvantage of higher energy prices is thus "shared" by industrial producers across the EU, even though compensation and subsidies for energy-intensive producers are already a matter of national policies. At the EU27 level, the possible introduction of CBAM (carbon tariffs) may significantly impact exports in the coming years. Another reason is that developed Western European countries have GDP and exports primarily generated by high-tech products, the production of which is less energy-intensive or even new Member States with a GDP generated primarily by commercial services (e.g., Croatia). This fact makes the creation of GDP and the export of services (e.g., active tourism) relatively immune to high energy prices. As our analysis confirmed, the decisive factor was and will be labour productivity in the EU as suggested by Dechezlepretre and Sato (2017). Another possible explanation of the missing relation between energy costs (electricity) and export value, which requires a significantly deeper analysis, is a possible presence of the Porter effect. This means that industrial producers from the EU have higher energy costs and, as Faiella and Mistretta (2020) show, mainly due to decarbonisation measures. However, these high costs can be compensated for by solutions in the field of energy efficiency or innovations in production equipment (investment goods). Our findings of a statistically insignificant effect of UEC_{EE} on export competitiveness thus confirm the findings of the Oxford Institute for Energy

Studies (2014) that there is no significant negative impact of decarbonisation in the EU at the general level.

The statistically insignificant impact of UEC_{EE} on the overall exported value-added of the EU countries was already indicated by the study of Dechezlepretre and Sato (2017) or Venmans, Ellis and Nachtigall (2020). By panel regression examining UEC_{EE} directly, we also confirmed the original conclusion of Lindén (2017), since the construction of UEC_{EE} itself, reflects the increase in electricity prices, including the amount of electricity consumed. Energy savings eliminate part of the rise in prices caused by decarbonisation (a decrease in energy intensity). In this context, it is necessary to emphasise that the data included in the regression analysis are up to 2018, since the most recent OECD Trade in Value-Added database is released in 2021. Therefore, periods of sharp growth in energy prices in 2021 and especially the energy crisis in 2022 were not reflected yet, representing a new, unprecedented situation that may have a significantly harmful impact on European industrial producers. The effect has to be better clarified by further research.

At the level of specific industries, or segments of countries, however, we confirm the findings of Dechezlepretre and Sato (2017), Cambridge Econometrics (2018), and Frauenhofer (2016) namely that a negative impact on export competitiveness was identified for some industries with an increase in UEC_{EE}. Specifically, the statistically significant negative impact of UEC_{EE} on energy-intensive industries' export in the EU 13 countries, especially the production of base metals, was confirmed. Paradoxically and contrary to the studies mentioned above (Lindén, 2017; Baláž and Bayer, 2019; Kumar and Prabhakar, 2020), and, e.g., research in the economy of France (Bureau et al., 2013), at the level of the EU and even at the level of the less developed countries of the EU 13, our study did not demonstrate a significant effect on the exported added value in the sector of chemical industry and chemical products, production of paper and cellulose or non-ferrous metals and minerals. Absent causality was also confirmed in the case of time-shifted variables model modification.

The differentiated impact of demanding decarbonisation on the growth of UEC_{EE} in the countries of the original EU15 and the new EU Member States (mainly industrially oriented CEE countries) can be characterised as a very significant finding. The difference is not very significant, but the panel regression confirmed that in the case of the new (more industrially oriented) EU Member States, the impact of UEC_{EE} on export performance is not only statistically significant but also higher than in the EU15 countries: a 1% increase in EUC_{EE} represents a decrease in industrial exports expressed through value added by 0.11% in the case of the EU28, but the same increase will generate a decrease in the EU13 countries (industrially oriented new EU members) by up to 0.14%. This finding widens the finding of Faiella and Mistretta (2020 and 2022) and has a fundamental implication for the sensitivity of decarbonisation policy settings across the EU. Huge environmental ambitions transformed into higher energy prices can be considered a significant risk, especially in the industrial production of "new" Member States outside the EU15. In case of a revolutionary and uncontrolled transition to a low-carbon economy in this region of industrialised countries, this may generate the risk of asymmetric shocks to the competitiveness of industrial exports. Important studies have dealt with the risk of an inadequate response of the industry to stricter environmental measures since the beginning of the 1990s. M. E. Porter (1993) predicts even a possible adverse scenario after introducing stricter environmental measures - the "pollution haven hypothesis" - when companies lose their competitiveness and leave for industrial production in foreign markets with less stringent legislation.

Possible limitations of our model and findings can be attributed to the availability and up-to-dateness of the data, since the most recent variables are several years old in the case of data from the TiVA database (OECD, 2021), which limits the applicability and up-to-dateness of measures recommended for policy design. The panel regression brought very important findings, but these findings are derived from the total export or export of industries of EU member countries, regardless of whether it is intra-trade or extra-trade. In this context, it would be worth considering the use of panel regression using UEC, or UEC_{EE} and TiVA parameters for bilateral export flows using gravitational models among all countries (as proposed by Faiella and Mistretta, 2022), which, however, is methodologically extremely challenging since the data of TiVA is not very recent. Further research to better explain the sub-sector industry's exports using RUEC (as proposed by Kaltenegger et al., 2017) could also interpret or improve some of the findings of our study. A stimulus for further research could be the examination of UEC_{EE} at the level of specific EU countries, which reinforces that energy policy and especially the pricing of electricity, including feed-in tariffs, are determined at the level of Member States, not the EU as a whole.

Conclusions

The EU as a leader in the fight against climate change and an urgent need for import substitution of fossil fuels from the Russian Federation makes a decarbonisation of the EU economy one of the most important political priorities for the coming decades. However, the EU industry has lost its position and its international competitiveness to an unprecedented extent. Evaluating the impact of EU energy policy (and especially decarbonisation) on export competitiveness is a topic of economic research throughout the EU, especially in CEE countries, where asymmetric impacts have tremendous potential for industrial cost competitiveness.

From a theoretical point of view, our research contribution represents a significant shift in the evaluation of decarbonisation, not only in electricity prices, but also by applying a more complex UEC_{EE} parameter. This parameter allows the projection of energy savings to compensate for higher electricity prices. The second fundamental theoretical shift is the character of the explained variable. The domestic added value in exports used in the model much assesses more accurately the impact of energy costs on export performance growth or redirection of GVCs in energy-intensive industries outside the EU. The sensitivity of increasing energy costs' impact to changes in exports is approximately one-tenth compared to the factor of labour productivity. Identifying the highest EUC_{EE} values in the CEE countries' (resp. EU13) can be considered a fundamental finding within the research, which only confirms the validity of investigating this impact in the region.

Among the most important findings of research based on panel regression is the absence of a statistically significant relationship between the growth of value added in exports and the value of unit energy costs (electricity). This may indicate the presence of the Porter effect, but further research is needed in this area. On the other hand, our analysis confirmed the significant impact of unit energy costs (especially the importance of electricity prices) in the industry at the level of EU28 (today EU27). One of the most important findings points to an even higher sensitivity to energy costs in the case of EU 13 countries (primarily from CEE). In specific industrial sectors, the causality of energy costs and added value in exports has been demonstrated only in the case of the production of basic metals. This strengthens the arguments in favour of stimulating exporters at the overall level of EU industrial policy. In the new policy design, we recommend that new European legislation should more appropriately consider the aspect of the future industrial competitiveness of countries outside the original EU15 when making ambitious commitments to decarbonisation. It is also appropriate to consider additional incentives and financing schemes for innovative “green” projects upgrading the production capacities of these industries in Eastern Europe.

A possible extension of our research represents the connection of the ability to absorb growing energy costs in the EU due to decarbonisation (and emission allowances) through innovations stemming from applied science and research outputs. This so-called Porter effect is needed to be achieved by industrial producers of the EU. However, we did not clearly confirm the Porter effect, and the variable R&D expenditures turned out to be statistically insignificant. Another area for the next research, especially in the more industrially demanding CEE region, is the examination of UEC_{EE} and export performance at the level of individual EU Member States, where the effects can be different and thus the targeting and efficiency of incentives. Investigating the feed-in tariffs themselves and their impact on cost competitiveness is another separate topic of research, since not all EU countries have this tariff in place.

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Appendix 1

Values of UEC_{EE} (electricity) in the industry of the selected EU Member States

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Austria				0.032	0.036	0.037	0.038	0.040	0.038	0.046	0.046	0.044	0.041	0.042	0.039	0.037	0.034	0.034
Belgium	0.057	0.057	0.056	0.057	0.057	0.056	0.071	0.064	0.063	0.061	0.062	0.063	0.063	0.062	0.062	0.059	0.059	0.054
Bulgaria					0.101	0.092	0.086	0.079	0.088	0.073	0.068	0.060	0.066	0.070	0.070	0.064	0.064	0.060
Cyprus	0.036	0.041	0.036	0.038	0.035	0.037	0.049	0.048	0.069	0.052	0.061	0.071	0.084	0.078	0.072	0.049	0.041	0.048
Czech Rep.	0.043	0.040	0.042	0.039	0.041	0.045	0.049	0.047	0.050	0.052	0.049	0.048	0.048	0.047	0.038	0.033	0.029	0.027
Denmark	0.017	0.018	0.020	0.022	0.020	0.020	0.022	0.018	0.022	0.020	0.020	0.020	0.019	0.020	0.019	0.018	0.017	0.016
Estonia			0.056	0.052	0.053	0.048	0.049	0.045	0.040	0.045	0.051	0.045	0.051	0.054	0.046	0.046	0.044	0.040
Eurozone			0.025	0.025	0.025	0.025	0.026	0.026	0.024	0.026	0.032	0.032	0.034	0.038	0.035	0.033	0.031	0.028
EU15				**0.034**	**0.034**	**0.036**	**0.038**	**0.038**	**0.036**	**0.036**	**0.036**	**0.037**	**0.039**	**0.039**	**0.039**	**0.035**	**0.033**	**0.032**
EU27						**0.035**	**0.038**	**0.038**	**0.036**	**0.036**	**0.035**	**0.036**	**0.037**	**0.038**	**0.037**	**0.035**	**0.032**	**0.031**
France	0.030	0.029	0.029	0.030	0.030	0.031	0.030	0.029	0.028	0.030	0.031	0.034	0.035	0.035	0.036	0.036	0.033	0.032
Germany	0.030	0.031	0.031	0.037	0.037	0.040	0.041	0.042	0.037	0.039	0.038	0.041	0.040	0.044	0.045	0.041	0.039	0.037
Hungary	0.038	0.038	0.039	0.036	0.035	0.034	0.032	0.037	0.044	0.049	0.043	0.042	0.064	0.064	0.055	0.051	0.047	0.045
Ireland	0.019	0.015	0.016	0.015	0.015	0.019	0.024	0.024	0.026	0.022	0.021	0.022	0.025	0.027	0.025	0.012	0.011	0.010
Italy	0.056	0.060	0.057	0.060	0.058	0.060	0.068	0.069			0.059	0.063	0.074	0.067	0.065	0.060	0.055	0.051
Malta	0.036	0.041	0.042	0.042	0.047	0.047	0.056	0.059	0.068	0.064	0.069	0.073	0.078	0.075	0.075	0.064	0.056	0.056
Netherlands	0.035	0.035				0.042	0.043	0.044	0.036	0.038	0.036	0.034	0.029	0.030	0.028	0.028	0.029	0.027
Poland	0.044	0.048	0.050	0.054	0.045	0.041	0.040	0.040	0.044	0.046	0.045	0.043	0.042	0.042	0.036	0.038	0.037	0.032
Portugal	0.045	0.045	0.046	0.047	0.048	0.051	0.056	0.058	0.055	0.054	0.053	0.061	0.067	0.065	0.059	0.056	0.053	0.054
Romania				0.075	0.088	0.097	0.078	0.066	0.049	0.041	0.038	0.035	0.043	0.038	0.039	0.039	0.036	0.035
Slovakia	0.082	0.081	0.075	0.087	0.079	0.075	0.071	0.076	0.083	0.097	0.072	0.077	0.081	0.081	0.070	0.061	0.061	0.063
Slovenia	0.061	0.058	0.055	0.058	0.055	0.062	0.063	0.067	0.058	0.053	0.061	0.062	0.062	0.060	0.052	0.050	0.047	0.042
Spain	0.047	0.041	0.037	0.038	0.039	0.048	0.044	0.043	0.044	0.043	0.039	0.040	0.044	0.046	0.045	0.042	0.039	0.036
Sweden	0.034	0.034	0.029	0.049	0.046	0.044	0.052	0.048	0.052	0.053	0.053	0.050	0.047	0.045	0.040	0.036	0.036	N.A.

Note: the values represent UEC in electricity (e.g. value of 0.060 = share of 6.0% on value added)

Source: Own elaboration based on Eurostat data, 2022

Appendix 2
Descriptive statistics

	Total all NACE activities (EU 28)					
Variables	**Mean**	**Min.**	**Max.**	**Std. Dev.**	**Miss. obs.**	**Time**
EXGR_DVA	164,950.00	4,402.90	1,193,900.00	232,180.00	0	2008-2018
UEC_EE	0.03	0.01	0.05	0.01	32	2008-2017
GDP_ppempl	89,692.00	41,496.00	270,960.00	38,687.00	0	2008-2018
RandD_sh	1.56	0.38	3.73	0.88	0	2008-2018
l_EXGR_DVA	11.13	8.39	13.99	1.41	0	2008-2018
l_UEC_EE	- 3.67	- 4.94	- 2.91	0.39	32	2008-2017
l_GDP_ppempl	11.34	10.63	12.51	0.35	0	2008-2018
	Total all NACE activities (EU 13)					
EXGR_DVA	37,039.00	4,402.90	202,280.00	40,842.00	0	2008-2018
UEC_EE	0.03	0.02	0.05	0.01	14	2008-2017
GDP_ppempl	63,546.00	41,496.00	91,368.00	10,071.00	0	2008-2018
RandD_sh	0.98	0.38	2.56	0.53	0	2008-2018
l_EXGR_DVA	10.04	8.39	12.22	0.97	0	2008-2018
l_UEC_EE	- 3.41	- 3.96	- 2.91	0.24	14	2008-2017
l_GDP_ppempl	11.05	10.63	11.42	0.16	0	2008-2018
	Energy intensive and non - intensive sectors (EU 28)					
EXGR_DVA	5,616.60	1.70	207,730.00	14,904.00	0	2008-2018
UEC_EE	0.11	- 27.91	3.34	0.64	523	2008-2017
GDP_ppempl	89,692.00	41,496.00	270,960.00	38,631.00	0	2008-2018
RandD_sh	1.56	0.38	3.73	0.88	0	2008-2018
l_EXGR_DVA	6.95	0.53	12.24	2.08	0	2008-2018
l_UEC_EE	- 2.80	- 10.96	1.21	1.26	525	2008-2017
l_GDP_ppempl	11.34	10.63	12.51	0.35	0	2008-2018
	Energy intensive sectors (EU 28)					
EXGR_DVA	4,316.00	1.70	79,688.00	9,656.70	0	2008-2018
UEC_EE	0.16	- 27.91	3.34	0.86	307	2008-2017
GDP_ppempl	89,692.00	41,496.00	270,960.00	38,637.00	0	2008-2018
RandD_sh	1.56	0.38	3.73	0.88	0	2008-2018
l_EXGR_DVA	6.88	0.53	11.29	1.98	0	2008-2018
l_UEC_EE	- 2.17	- 6.46	1.21	0.91	309	2008-2017
l_GDP_ppempl	11.34	10.63	12.51	0.35	0	2008-2018

Source: Own elaboration