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The effect of energy prices on the competitiveness of the Polish and European economies

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Abstract

This paper assesses the impact of energy price fluctuations in recent years on the competitiveness of Polish and European economies. Using the Leontief price model and input–output tables, we evaluate both direct and indirect effects of price shocks in gas, oil, coal, and electricity on aggregate export prices. Reactions to hypothetical 100% price shocks reveal that European economies are particularly sensitive to oil and electricity, while gas and coal exert smaller but sector-specific effects. Model responses to historical price changes between 2015–2019 and 2020–2024 indicate substantial cross-country variation in export price, with the highest increases observed in the Netherlands, Lithuania, and Greece, and moderate effects in Poland. In most countries, oil and gas price shocks dominate the overall impact, whereas coal affects exports primarily in countries with high coal dependence. The findings highlight the differential sensitivity of national economies to energy price volatility and its implications for export competitiveness.

Keywords: energy shocks, price pass-through, price competitiveness, Leontief price model

JEL: C67, E17, E31, Q43

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1. Introduction and literature overview

The paper is empirical and aims to assess the impact of energy prices on the price competitiveness of the Polish economy and other (primarily European) economies. In the analysis, we focus on various energy carriers, such as natural gas, coal, crude oil, and electricity. We first discuss the dispersion in the price levels faced by enterprises from different countries, as well as the degree of exposure of various economies to energy carrier prices. In the former case, we additionally emphasize the role of tax policies in generating cross-country price dispersion. In the latter case, we apply the Leontief price model, which allows us to calculate both the direct and indirect effects of energy prices. As we aim to analyse the competitiveness in international markets, we estimate the pass-through of energy prices to export prices. Finally, we combine information on energy price changes with countries' exposure to them and discuss the effects of actual changes in energy prices (between 2015–2019 and 2020–2024) on export competitiveness.

Over the last decades, the impact of rising energy carrier and electricity prices on competitiveness has been frequently analysed, mostly in the context of regulations resulting from climate policy implementation (Cohen, Tubb 2018; Dechezleprêtre, Sato 2017; Rammer et al. 2017). Indeed, market instruments of climate policy (e.g. carbon taxes, emission permits) have been introduced to internalize the negative environmental externalities of using fossil fuels in production and energy generation, resulting in higher energy carrier and electricity prices, with potentially harmful effects on competitiveness. Dechezleprêtre and Sato (2017) proposed a useful classification of the potential impacts of increasing energy carrier and electricity prices on competitiveness. The direct effect consists of changes in production costs and may be called the first-order effect. Firms' adjustments concerning pricing, output, or investment are referred to as second-order effects. Further adjustments, e.g. in technology and innovation, represent so-called third-order effects. If the first-order and second--order effects of rising energy prices materialize to a different extent, the relative competitiveness of the countries changes. Moreover, some producers tend to relocate their activities into less affected countries, in line with the pollution haven hypothesis (André et al. 2023; Dechezleprêtre, Sato 2017). However, some firms may adjust through investment and innovation, reducing energy use and boosting TFP (third-order effects), thus enhancing their competitiveness, as postulated by the Porter hypothesis[1] (Ambec et al. 2013).

Empirical literature on the impact of environmental regulations on firms' economic performance and competitiveness has sought to determine whether, in particular cases of climate policy implementation, a country or group of countries experiences a deterioration in economic performance (when first-order and second-order effects dominate) or an improvement (when third-order effects prevail). Thus, econometric literature finds varying effects of environmental regulations on firms performance. For instance, Rammer et al. (2017) found no significant impact of energy price changes on exports of firms of selected European countries. Marin and Vona (2021), Sato and Dechezleprêtre (2015), Faiella and Mistretta (2020) and Astrov et al. (2015) reported that higher energy prices induce either declines in TFP or a reduction of the price competitiveness of European exports.

[1] Improvement of competitiveness resulting from this type of adjustment is called the 'strong' version of the Porter hypothesis, while reactions of firms to regulations (and related price increases) through innovations means the 'weak' version of this hypothesis.

In contrast, Calì et al. (2023) conclude that companies adapting to rising energy costs are able to maintain, or even improve, their economic performance and competitiveness in line with the Porter hypothesis (this mostly applies to large companies investing in R&D). Similar results, pointing to a positive effect of an energy shock on economic performance, were found by Amann and Grover (2023) in the case of Chile and by van Leeuwen and Mohnen (2016) for Denmark. Aterido, Iootty, and Melecky (2025) stresses that a positive effect emerges if firms reduce the energy intensity of production.

The impact of rising energy prices on economic performance and competitiveness was also studied using structural models. Pedersen et al. (2014) used an input–output model (similar to ours) to assess how energy intensity at a sectoral level affects the competitiveness of the Danish industrial sector relative to other countries. Chan, Manderson, and Zhang (2017) employed a Melitz-type trade model calibrated with multi-country input–output data to demonstrate that a carbon tax, unilaterally raising energy prices in the European Union, would negatively affect EU-wide manufacturing exports. Van Voss et al. (2025) concluded (using a static CGE model) that Dutch industrial companies experienced a loss of competitiveness compared to the EU average between 2015 and 2023, due to the relatively higher energy intensity of key sectors (e.g. the chemical industry). Both input–output and CGE approaches account for the full (direct and indirect) reaction of energy cost to the increase of energy carriers' prices. Moreover, CGE models allow for substitution effects induced by rising energy prices. However, these models only allow an investigation of the responses of relative prices. If one aims to assess the changes in price levels, like in our case, the input–output models are the natural choice, with the cost of a restrictive assumption on the substitution elasticities.

Some general conclusions emerge from the literature. First, the overall effects of environmental regulations are relatively small in macroeconomic terms and other factors with a higher cost share (e.g., labour costs) play a more important role in shaping competitiveness. Second, when observed, the results are concentrated in specific sectors and groups of firms (see e.g. Marin, Vona 2021). Third, positive impact of environmental regulations on economic performance is more frequently found in recent studies (see, e.g., Ambec et al. 2013), reflecting either solid businesses adjustment to regulations and stringency of policies, or the improvement in scientific methods properly modelling these processes.

There are also some papers on the impact of energy price shocks resulting from the Covid-19 pandemic and the Russian aggression against Ukraine. However, they concentrated predominantly on either GDP (see Zhao et al. (2023); Bachmann et al. (2022); Borin et al. (2022) but also Sokołowski, Antosiewicz and Lewandowski (2022); and Gradzewicz et al. (2024) in the case of Poland) or inflation (see Kilian, Zhou 2023; Neri et al. 2023; Alvarez, Kroen 2025). Our analysis contributes to this strand of literature by focusing on price competitiveness.

Our contribution to literature is empirical. First, our paper attempts to determine the impact of energy price changes observed in recent years on the cost competitiveness of Poland and over twenty European countries. Second, by cautious choice of data sources, we try to separate the effects of various energy carriers: natural gas, oil, coal, and electricity. In most of the studies cited above these are mixed with other commodities due to sectoral aggregation.

The rest of the study is organized as follows. Next, we discuss the methodology and data sources applied. Then we present our main results: what is the sensitivity of export prices to changes in prices of energy carriers (gas, oil, coal and electricity) and how did economies react to real-world energy price increases. Next, we present robustness checks and conclude.

2. Methodology and data sources

We aim to assess the effects of energy prices (natural gas, oil, coal, and electricity) on the competitiveness of European economies (and some important non-European ones).[2] First, we show the dispersion of prices faced by enterprises across countries. Energy prices vary considerably not only due to the formation of base prices (e.g. contracts, share of domestic extraction/production), but also due to the structure of national tax systems. We discuss the extent to which price dispersion results from taxes levied by governments.

Second, we calculate the country-specific sensitivity of export prices to energy prices. This allows us to assess how vulnerable a given country is to fluctuations in the prices of various energy carriers. We use the Leontief price model, as it captures both the direct effect of energy prices and the indirect effect stemming from the transmission of price increases across sectors, triggered by a rise in the price of an energy carrier (a detailed model description is provided in Appendix). Thus, the indirect effect includes price adjustments in other industries in response to higher prices in the energy industry affected by the shock.[3] In a standard Leontief price model, exogenous shocks originate from value added (e.g. wage increases). As we aim to track the response of endogenous prices to a shock in the price of a single good, we follow Bun (2018) and use exogenous wedges on prices as the source of the shock (see Appendix for details). Moreover, since we are interested in export prices, we aggregate sectoral prices into aggregate export prices, using exports as weights. To allow for cross-country comparison, we examine the reaction of export prices to a shock of a common magnitude – a hypothetical 100% increase. This enables us to compare both (1) the sensitivity of export prices to different energy carriers, and (2) to assess cross-country differences in sensitivity to a common price increase of a given energy carrier. One should bear in mind that the Leontief model imposes a set of restrictive assumptions. In particular it lacks the substitution effect and assumes a closed economy. The first introduces an upward bias in the magnitude of price reactions, as firms cannot substitute away the pricier energy carriers,[4] but should not affect the dispersion in cross-country responses to energy price shocks. Moreover, it suggests the results should be interpreted as short-term. To address the second caveat, we define the Leontief matrix in terms of the total supply to the domestic market instead of domestic output, but still we do not model the substitution possibilities across domestic and foreign supply.

Third, after analysing both the dispersion of energy carrier prices and the dispersion in countries' sensitivity to energy price shocks, we investigate how actual changes in energy prices faced by the analysed countries affected export prices. This allows us to gauge the extent to which energy price shocks in the early 2020s may have affected the price competitiveness of Poland relative to the EU and selected other countries. One should bear in mind, that we define competitiveness narrowly. On the one hand, it allows us to concentrate on a specific channel of a pass-through of energy prices

[2] For an extended comparison, we also use the following country groups: CEE5 (Bulgaria, Czech Republic, Hungary, Romania and Slovakia), CEE9 (Bulgaria, Czech Republic, Estonia, Hungaria, Latvia, Lithuania, Romania, Slovakia, Slovenia) and EU-WEST (Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Italy, Ireland, Netherlands, Portugal, Spain, Sweden). For aggregation we use export volume weights.

[3] It is worth emphasizing that the results of the above analysis may underestimate the impact of energy price increases on the costs and prices of exporters from narrowly defined industries, such as the production of fertilizers and nitrogen compounds, or cement production, where the energy intensity of production is much higher. The lack of data, captured in the format of cross-country comparable input–output tables, prevented the authors from analyzing at this level of detail.

[4] However, econometric estimates of elasticity of substitution across material use in production find them close to zero, see e.g. Atalay (2017). The substitution possibilities between energy carriers and other materials seem to be even more limited.

to export prices. On the other hand, it leaves the other channels fixed and the effects of energy prices for overall competitiveness may differ from ours.

We use data on natural gas and electricity prices faced by enterprises from Eurostat. Prices are categorized into energy consumption bands, and we use the median range to ensure the completeness of national data. For oil prices (specifically PB95 gasoline and ON diesel), we use data published in the European Commission's Weekly Oil Bulletin. Both datasets allow us to distinguish between net and gross prices. In the absence of a comparable international database on coal prices, we use data published by ARP SA (the PSCMI1 index)[5] for Poland, and the coal price index for the ARA market for other European economies. Price trends over time (for gas, liquid fuels, and electricity) are presented in Appendix. Additionally, we use the Statistical Review of World Energy (2024)[6] to compare coal prices outside Europe. Where feasible, we separate VAT (and other refundable taxes[7]) from nonrefundable taxes in energy prices. Moreover, we use prices net of VAT in defining actual price shocks in the final part of the analysis.

Most available international input–output tables disaggregate the economy into NACE industries. This substantially limits the scope of energy-related analysis, as individual energy carriers (such as gas or oil) are included in different industries (mining, manufacturing, and energy generation). To calibrate the Leontief price model, we therefore employ input–output tables prepared by the European Commission's research unit, the Joint Research Centre (JRC)[8] for all European countries and selected non-European countries (e.g. China, the United States). These tables allow for a detailed decomposition of energy-related sectors, enabling the precise implementation of shocks. Moreover, the consolidation of all national I-O tables in a centralized repository guarantees methodological consistency and comparability. We use tables constructed for 2020.

3. The sensitivity of exports to energy prices

3.1. Gas prices

Poland is among the countries within the EU with the highest gas prices for firms (see Figure 1). In 2024, the net gas price in Poland was 29% higher than the EU average and above the average values in other CEE countries, with only firms in Finland and Slovakia facing higher prices. Despite relatively low nonrefundable taxes, Poland remains among the countries with high gross gas prices, at levels comparable to Hungary and Slovakia. The relatively high gas prices in Poland are primarily attributable to the high net price of gas rather than a high tax burden, which remains moderate, especially compared to Scandinavian countries such as Sweden, Finland, and Denmark, where net prices are among the lowest, but high refundable taxes place gross prices near the top in Europe.

Figure 2 shows the pass-through of gas prices to export prices (the reaction of average export prices to a 100% increase in gas prices), as described in the methodological section. The pass-through is small

[5] Agencja Rozwoju Przemysłu SA (Industrial Development Agency JSC). PSCMI1 is a price index for energy coal sold to industrial energy consumers in Poland.

[6] https://assets.kpmg.com/content/dam/kpmg/az/pdf/2024/Statistical-Review-of-World-Energy.pdf (access: 23 July 2025).

[7] Council Directive 2006/112/EC of 28 November 2006 on the common system of value added tax, OJ L 347, 11 December 2006, p. 1–118, Article 168.

[8] https://joint-research-centre.ec.europa.eu/index_en.

and does not exceed 0.8%, except in the Netherlands,[9] where it amounts to 2.6% (the Netherlands has substantial shares of gas in its exports and in its energy mix, translating into a high measure of direct exposure). Poland has limited exposure to fluctuations in gas prices, due both to the relatively small share of gas in energy and electricity generation (4.3% vs. 8.3% in CEE5) and to the relatively low dependence of industry on gas. Both Western European countries and many Central and Eastern European (CEE) countries are more exposed to gas prices than Poland. Export prices in most Western European countries, including Italy, Germany, and Spain, are relatively gas-dependent. In most countries, overall exposure is dominated by indirect effects (I-O adjustments, reflecting the reliance of other sectors on gas) rather than by the direct effect of a high share of gas in exports.

A country's export competitiveness is affected by both price levels and exposure to the energy carrier, as depicted in Figure 21. The figure shows that most countries with relatively high exposure to gas prices simultaneously face relatively low gas prices. A notable exception is the Netherlands, which exhibits both high price levels and high exposure. Moreover, exports from two countries with exceptionally high gas prices, Finland and Sweden, are only marginally exposed to these prices.

3.2. Prices of oil-related fuels

Fuel prices in Poland are among the lowest in the EU (see Figure 3) and close to the average in the CEE region. In 2024, the average gross price of diesel ON and PB95 in Poland was 97% and 99% of the CEE averages, respectively. Prices in Poland and most CEE countries are lower compared to many Western European countries, where fuel prices are typically higher due to greater tax burdens. In 2024, the average gross price of diesel ON and PB96 in Poland was 96% and 91% of the EU average, respectively. It is worth noting that, compared to gas prices, tax levies on oil-related fuels are generally higher, and their cross-country variation is relatively smaller.

The exposure of export prices to fuel prices (see Figure 4) is considerably higher than for gas prices (and also for coal prices, see next section). The CEE9 and EU WEST averages exceed 2%, much higher than exposures to gas prices. The relatively large impact of oil price shocks can be explained by the extensive use of oil in the economy, particularly in export-oriented manufacturing and transport sectors. In Poland, a 100% rise in oil prices leads to a 2.5% increase in the price of aggregate exports, which is close to the average. Approximately two-thirds of crude oil in Poland is used in production processes, mostly in manufacturing (around 47%, especially in the chemical and petrochemical sectors) and transport (approximately 44%), while the remaining one-third is consumed by households, primarily as vehicle fuel. Three countries have exports especially exposed to oil prices (with a pass--through exceeding 10%) – Greece, Russia, and Lithuania. In Lithuania, high exposure results from the substantial share of transport in GDP.

Among countries with exports relatively more exposed to oil prices, only the Netherlands and Finland face simultaneously high price levels (see Figure 22). Lithuania, despite its high exposure, faces relatively low fuel prices. The exposure of other countries with high price levels (Belgium, France, Italy) is relatively modest, and the same applies to Germany and Denmark.

[9] A more extreme exception among analysed countries is Russia, where a 100% increase in gas prices translates into a 6.9% price increase of an export good, reflecting the enormous energy intensity and gas dependence of the Russian economy.

3.3. Coal prices

The global price of coal[10] exhibited a downward trend between 2011 and 2020, but increased sharply during 2021–2022, particularly in Europe (see Figure 5). The price hikes were driven by concerns about energy security, trade disruptions, and high gas prices. Since 2023, global prices have started to decline, although they remain above pre-pandemic levels. Poland maintained relatively low coal prices until 2021; however, the subsequent price increase, although delayed, has not yet declined, and in 2023 the price of coal in Poland remained comparatively high. It reached 167 USD/t, compared to 74 USD/t in the United States, 130 USD/t in Europe, and 121 USD/t in China. The delayed increase in Poland was driven by several factors, including long-term contracts between the energy sector and coal mines, the embargo on Russian coal imports, limited domestic supply, rising logistics and energy costs, and increased demand due to high natural gas prices.

The exposure of most European countries to coal (see Figure 6) is very limited and substantially lower than exposure to gas prices. This is due to the limited role of coal in electricity generation, as well as its negligible use in manufacturing industries in most countries. Notable exceptions are Bulgaria and Poland (and, to some extent, the Czech Republic), where coal plays a substantial role in the electricity mix (in Poland, the share of coal in electricity generation amounts to 74%, according to the JRC I-O tables we use). Nevertheless, the exposure of exports in these countries to coal does not exceed 1% and remains substantially lower than in Russia and China, and is comparable to levels calculated for the United States.

3.4. Electricity prices

There is significant variation in electricity prices across European countries, both in net and gross terms (see Figure 7). Poland is among the countries with relatively low net electricity prices for firms, but simultaneously with high gross prices, mainly due to exceptionally high nonrefundable tax rates. In 2024, the net price of electricity was 20% lower than the EU average and close to the relatively low levels observed in Spain and Portugal. However, the gross price was almost 50% higher than the EU average. Electricity taxation in Poland (44% above the EU average) is among the highest in the EU and drives electricity prices faced by the corporate sector to relatively high levels compared to other European countries (slightly lower than in the Netherlands, Hungary, and Germany).

The exposure of European economies to electricity prices (see Figure 8) is much higher than to gas or coal prices and, in most cases, comparable to exposure to oil prices. This is because electricity represents a substantial component of the energy bundle, which includes energy carriers and electricity (in Poland, approximately 46%, and in European countries ranging from approximately 40% to 65%). Apart from Russia, the only European country with exceptionally high export exposure to electricity prices is Bulgaria, where a 100% rise in electricity prices passes through to a 10% increase in export prices. In other countries with relatively high exposure, the pass-through ranges between 4% (Romania, the Czech Republic, and Portugal) and 6% (Latvia and Finland). Ireland and the United Kingdom have the lowest exposure, not exceeding 2%. A similarly low exposure to electricity prices can be observed in the United States. In all countries, the overall effect is dominated by indirect effects of electricity price increases, reflecting the dependence of virtually all sectors of the economy on electricity.

[10] A cross-country comparison of coal prices is limited due to lack of available country-specific data.

In Poland, a 100% increase in electricity prices translates into a 3.2% rise in export prices, which is clearly lower than in the countries of the region (by 0.8 pp. for CEE5) and slightly higher than in Western European countries (by 0.8 pp.).

Figure 23 shows that countries substantially exposed to electricity prices (including Bulgaria, the most exposed) simultaneously face relatively low electricity prices. Conversely, countries facing relatively high electricity prices, such as Ireland, Germany, and the Netherlands, are only mildly exposed to these prices. No country simultaneously faces both high electricity prices and high exposure to them.

4. Real-world impact of energy prices on competitiveness

In previous sections, we described cross-country differences in both net and gross prices of energy carriers and electricity, as well as differences in countries' exposure to energy price shocks. Here, we combine these results and show how observed changes in energy carrier prices[11] affected the export competitiveness of selected economies. We define the price shock as the change in average prices during 2020–2024 compared to the 2015–2019 average, using gross prices net of VAT and other refundable charges.[12] Next, we feed these shocks into the Leontief price model and examine their impact on the price of an average export good.

Figure 9 to Figure 11 show the observed changes in average prices for gas, oil, and coal (for long--term data on gas and liquid fuels, see Figure 13 to Figure 18, for coal see Figure 5). There is substantial variation in gas price changes across EU countries. While EU prices increased on average by almost 90%, gas prices rose by over 120% in Finland and Hungary, and by close to 60% in Austria, Greece, and Slovenia. Poland experienced an above-average increase of 112% in gas prices. There are also noticeable differences across countries in oil price changes, although the EU average increase is smaller (about 20%). The highest increases (over 28%) were observed in Latvia and Estonia, while the lowest occurred in Malta, Slovenia, and Italy. The increase in oil prices in Poland (22%) is close to the EU and CEE9 averages. Coal prices, for which data are more limited, increased by 110% in Europe, compared to the United States and China. In Poland, coal prices increased less than the European average, as most coal used by the energy sector is domestically extracted and subject to long-term contracts.

Figure 12 (see also Table 2) presents how observed changes in energy carrier prices propagate through the economy and ultimately translate into changes in the price of the average export good.[13] We excluded electricity prices as a direct source of shocks, as the energy carriers we consider (gas, coal, and oil) also feed into electricity prices through country-specific electricity mixes, thereby affecting export prices endogenously. There is substantial dispersion in the effects of price shocks on export prices, with the highest impact observed in the Netherlands, Lithuania, and Greece (over a 3% increase in export prices) and the lowest in Austria, Slovenia, Ireland, and Luxembourg (less than 0.5%). In Poland, the impact is above average, amounting to a 1.3% increase in export prices.

[11] We decided to exclude electricity from the definition of the shock. Thus, the rise in electricity prices, which is present in the calculations due to input–output connections, and affects export prices, is limited only to the extent that can be attributed to rising gas, coal and oil prices.

[12] In the absence of any internationally comparable information on taxes levied on coal, we assumed no change in refundable tax rates for the analysed period. We defined the oil prices as an average of EU PB95 and EU Diesel prices, net of VAT.

[13] The real shock is calculated using the same methodology as employed in the article Gradzewicz et al. (2024).

Despite the relatively moderate magnitude of oil price changes, the overall effect on export prices in most countries is driven primarily by oil price shocks, particularly in Lithuania, Greece, as well as Finland, Spain, France, and Sweden. This result is due to relatively high exposures (mostly direct, but also indirect) of export in many countries to oil prices (see the discussion in previous section and compare Figure 4 with Figure 2 and Figure 6), much higher than in case of coal and higher than the exposure to gas. Thus, a relatively mild shock is in effect extensively amplified and dominates the overall reaction of price competitiveness in many economies. Gas price shocks are also important in most countries, and their magnitude is in principle comparable (or smaller) to the effect of oil price changes. Only in the Netherlands, Romania, Hungary, and Italy does the effect of gas prices dominate the overall impact (these are the countries particularly exposed to gas prices, see Figure 2). However, the magnitude of export price responses is mainly driven by the large magnitude of the shock (compared to the shock to oil prices), rather than high exposures, as these are modest (except for the abovementioned countries, where the effect of gas shock dominates the overall effect). Finally, in most countries, coal price shock plays only a marginal role in the overall increase of export prices. This is mainly due to low exposure of many European economies to coal, as the coal prices rose considerably (see Figure 5). Only for countries heavily exposed to coal (Bulgaria, the Czech Republic, and Poland) is the negative effect of increased coal prices for export competitiveness significant, mainly through its role in the electricity mix.

5. Robustness check

We additionally check the robustness of our main results to selected aspects of our analysis, including: (1) the year of the input–output table used to calibrate the Leontief price model; (2) the use of alternative weights for aggregation of sector prices into economy-wide prices, and (3) calibrating oil shock with prices of crude oil shock instead of PB95/Diesel prices. In first two cases we keep the scale of the shocks unchanged, in the last case we recalculate the scale of the oil shock, keeping the other shocks unchanged.

Our main results are based on input–output tables for the year 2020 from the JRC-GEM-E3 recursive CGE model. As was discussed in the previous sections, this data source allows us to separate energy carriers. However, the years since 2020 were very turbulent, and included not only period of high energy prices, but also Covid-19 and ongoing transformation of energy sectors in many economies. To assess if these changes can potentially affect the sensitivity of economies to energy price shocks, we used model-generated I-O tables constructed for the year 2025 to calibrate the Leontief model. Thus, we examined how a different economic structure affects the analysed energy price shock, as structural changes – such as changes in energy efficiency, energy intensity, and the electricity generation mix – occur in national economies over time and are relevant to the subject of the study. The second column of Table 1 indicates that recent changes in the economic structure increased the vulnerability of all analysed economies to price changes of energy carriers (only the exposure to coal prices declined, at the expense of increased exposure to oil). It applies in particular to countries with already high exposure to fossil fuels (especially for Lithuania and Greece), but also for countries with low exposure to energy carriers.

Second, our baseline calculations are defined in terms of the price of an average export good and industrial prices are aggregated using export shares as weights. Here, we redefine the weights as

shares of industries in total output, thus the response is measured in terms of prices of output (cost of production of an average good, see a third column of Table 1). Reweighting significantly increase the average share of responses to an oil shock in total responses, from 41% to 50%. It reflects the facts that in most countries exports are more vulnerable to oil prices (but also in general to prices of fossil fuels) compared to supplies to domestic market. But the results indicate important heterogeneity – the increases of price sensitivities are observed in CEE countries, but also in Germany and Italy, whereas in most countries from Western Europe exports are less sensitive to fossil fuels than domestic supplies.

Third, in the baseline we used an average of PB95 and diesel prices to calibrate the magnitude of the oil price shock. This allows us to include the dispersion of country-specific price changes, including changes of taxes in the definition of the shock. However, the use of crude oil in economies is not only limited to a base of fuels for vehicles. Input–output tables include the other uses of crude oil, but we decided to check the robustness of main results to the definition of oil price shock. International prices are relevant in the case of crude oil, thus we use standardised Brent crude oil prices, a widely recognised benchmark for EU countries. The responses changed only slightly (see fourth column of Table 1), in both directions compared to the baseline. On average, the responses increased, as the weighted size of the shock to oil prices increased from 22% to 30%. This indicates that on average prices of fuels increased less than the prices of crude oil on international market. Simultaneously, a cross-country variation in differences with respect to the baseline indicates substantial cross-country differences to both (1) the pass-through of crude oil prices to fuel prices and (2) changes of oil-related taxes.

6. Conclusions

In this paper, we have attempted to assess how energy price fluctuations over approximately the last decade might affect the competitiveness of the Polish and European economies. In the first step, we analyse the dispersion of prices paid by enterprises, both net of taxes and including taxes other than VAT and other refundable taxes. In the second step, we calculate the country-specific sensitivity of export prices to energy prices. We use the Leontief price model, which allows us to consider both the direct effect of energy price increases and the indirect effect that materializes through the propagation of price changes across sectors according to inter-sectoral linkages. For calibration, we employ input–output tables (2020) compiled by the Joint Research Center of the European Commission for all European countries and some non-European countries (e.g. China, the United States), which include a detailed breakdown of energy-related sectors.

We apply a hypothetical 100% shock to the price of each energy carrier in each country to examine differences in sensitivity of export prices to energy price changes. Given our focus on competitiveness, we aggregate sectoral prices using exports as weights to obtain the aggregate export price. We find that among energy carriers, countries are most sensitive to oil, with aggregate export prices rising by over 2% for CEE9 and EU WEST (Poland – 2.5%) in response to a hypothetical 100% oil price shock. In the case of gas, the pass-through to export prices is much smaller (not exceeding 0.8%, except for the Netherlands; Poland – 0.2%) and is even more muted for coal (CEE9 – 0.3%, EU WEST – 0.1%, Poland – 0.8%). The relatively large impact of the oil price shock can be explained by the extensive use of oil outside electricity generation, particularly in export-oriented manufacturing (e.g. chemicals) and transport sectors. Finally, exposure of European economies to electricity prices is relatively high

(CEE9 – 4.1%, EU WEST – 2.5%, Poland – 3.2%), comparable to exposure to oil, reflecting the fact that electricity is a dominant component of the energy bundle in European countries, with shares ranging from approximately 40% to 65% (Poland – 46%).

Our analysis is complemented by a comparison of the reactions of individual economies to historically observed energy price changes between the pre-shock period (average prices 2015–2019) and the shock period (average prices 2020–2024). Overall, the effects of historically observed price increases in Europe on export prices exhibit substantial variation. The highest impacts are observed in the Netherlands, Lithuania, and Greece (over 3% increase in export prices), and the lowest in Austria, Slovenia, Ireland, and Luxembourg (less than 0.5%). The impact in Poland is 1.3%, slightly above the CEE average (1.3%) and higher than the EU WEST average (1%). In most countries, the overall effect on export prices is driven by shocks to gas and oil prices. However, in some countries, such as Lithuania, Greece, Finland, Spain, France, and Sweden, the largest contribution comes from oil price increases, despite the relatively moderate magnitude of oil price changes. Poland belongs to the group of countries (together with the Czech Republic, Bulgaria, Slovakia, and Slovenia) where increases in coal prices have a noticeable impact on aggregate export prices.

There is substantial variation in observed gas price changes across EU countries. While EU prices increased on average by almost 90%, gas prices rose by over 120% in Finland and Hungary, and by close to 60% in Austria, Greece, and Slovenia. Poland experienced an above-average increase of 112%.

There are also noticeable differences across countries in oil price changes, although the EU average increase is smaller (about 20%). The increase in oil prices in Poland (22%) is close to the EU and CEE9 averages. Coal prices, for which data are more limited, increased by 110% in Europe, compared to the United States and China. In Poland, coal prices increased less than in Europe, as most coal used by the energy sector is domestically extracted and subject to long-term contracts.

We supplemented our analysis with a robustness checks, indicating that post-2020 changes to the structure of analysed economies increased their sensitivities to the prices of energy carriers. Moreover, in CEE and some Western countries export prices are more vulnerable to prices of energy carriers than the prices on domestic markets, although in many West-European countries the inverse is true. Finally, our results are robust to the definition of oil price shock.

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Appendix

The Leontief model and the dual price model

The Leontief model (see Blait, Miller, 2009) imposes a set of assumptions, including:

– the Leontief (a bottleneck) production function that implies a constant proportion of intermediates in the production process of each good;

– the absence of substitution effects in the production process – demands for individual goods do not react to relative price changes; thus, the simulations with the Leontief model are referred to as short-term, and can be positively biased as the substitution reduces the magnitude of the price effects;

– closed economy,[14] implying the responses of domestic and foreign price are similar.

The Leontief model is a system of n production sharing equations of a sector i:

$$X_i = \sum\nolimits_{j\in 1,\ldots,n} v_{ij} + Y_i$$

where X_i is the output of the sector i, v_{ij} is the output of the sector i used in the production processes of the sector j, and Y_i is the final output of that sector.

Collecting the material intensity coefficients[15] $a_{ij} = \dfrac{v_{ij}}{X_j}$ into a matrix $A = \left[a_{ij}\right]_{n\times n}$ the model can be written matrix-wise as: $X = AX + Y$, which has a solution:

$$X = \left(I - A\right)^{-1} Y = LY$$

Leontief's dual price model, also known as the Ghosh model (cf. Blait, Miller 2009) focuses on the cost equations for a sector and separates values into prices and volumes (e.g. $v_{ij} = x_{ij} p_i$). Then:

$$X_j p_j = x_{1j} p_1 + x_{2j} p_2 + \ldots + x_{nj} p_n + v_j$$

where v_j is the value added generated in sector j. Dividing by X_j and taking into account that $x_{ij} p_i = a_{ij} X_j$ we get the price equation in the j-th industry:

$$p_j = a_{ij} p_1 + a_{2j} p_2 + \ldots + a_{nj} p_n + \frac{v_j}{X_j}$$

Denoting by $v_c = \left[\dfrac{v_j}{X_j}\right]_{n\times 1}$ and collecting the prices p_j into the vector p we obtain the equation $p = A'p + v_c$, which has a solution $p = \left(I - A'\right)^{-1} v_c$.

In the above system, prices are endogenous and therefore it is not possible to directly shock them. We include exogenous elements of prices, treated as a mark-up (which can be interpreted as a tax) on prices (see Bun 2018; Hebbink et al. 2018). For example, after imposing such a tax only on the k sector, the price equation for the j sector becomes:

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[14] When calibrating the model, we added imports to the definition of X_j (it becomes a total supply to domestic market). Similarly, we added exports to final demand Y_i.

[15] The coefficient tells how much of the products produced in sector i should be used per unit of output in industry j.

$$p_j = a_{ij}p_1 + a_{2j}p_2 + \ldots + a_{kj}p_k\left(1+\tau_k\right) + \ldots + a_{nj}p_n + \frac{v_j}{X_j}$$

In general, a price markup of this type can be introduced simultaneously on all prices. After introducing n independent price markups τ_i on all sectors, we can construct a diagonal matrix:

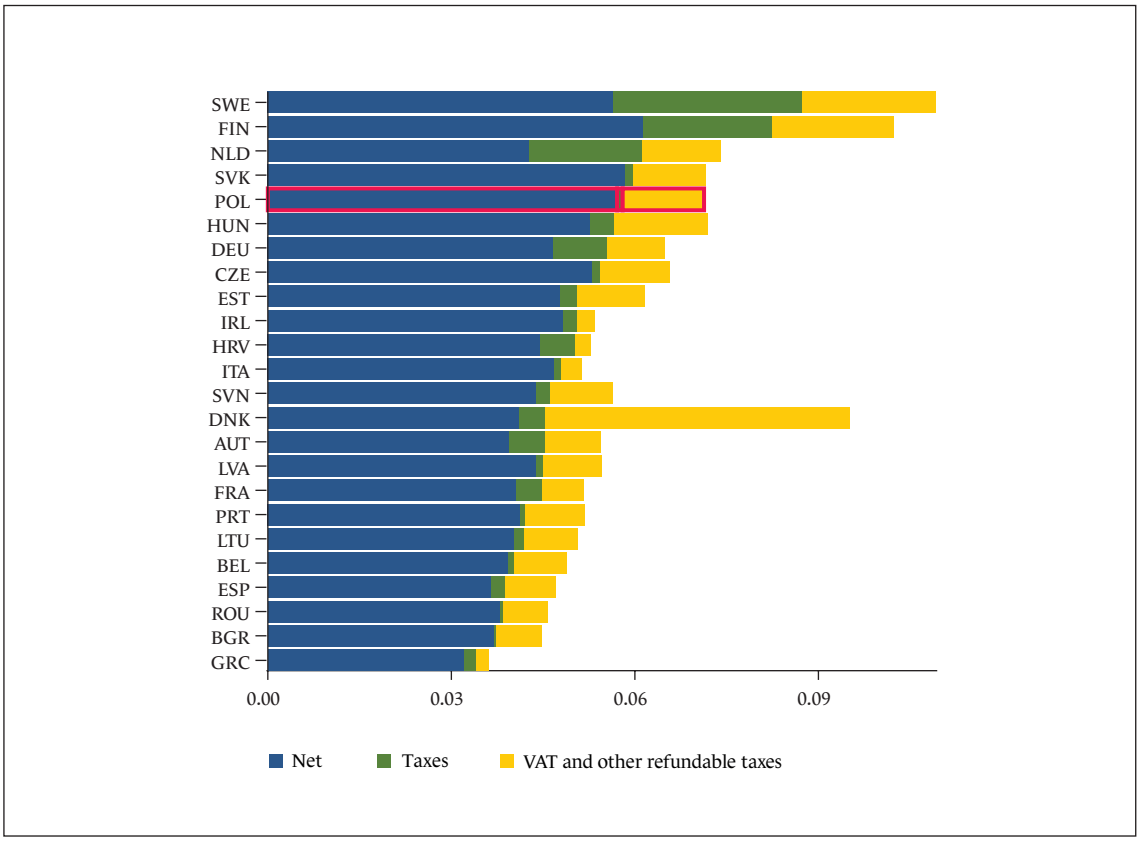
$$1+\tau = \begin{bmatrix} 1+\tau_1 & 0 & \cdots & 0 \\ 0 & 1+\tau_2 & 0 & \vdots \\ \vdots & 0 & \ddots & 0 \\ 0 & \ldots & 0 & 1+\tau_n \end{bmatrix}_{n\times n}$$

Then the price model containing the exogenous price component becomes $p = A'p\left(1+\tau\right)+v_c$, with the solution:

$$p = \left(I - A'\left(1+\tau\right)\right)^{-1} v_c$$

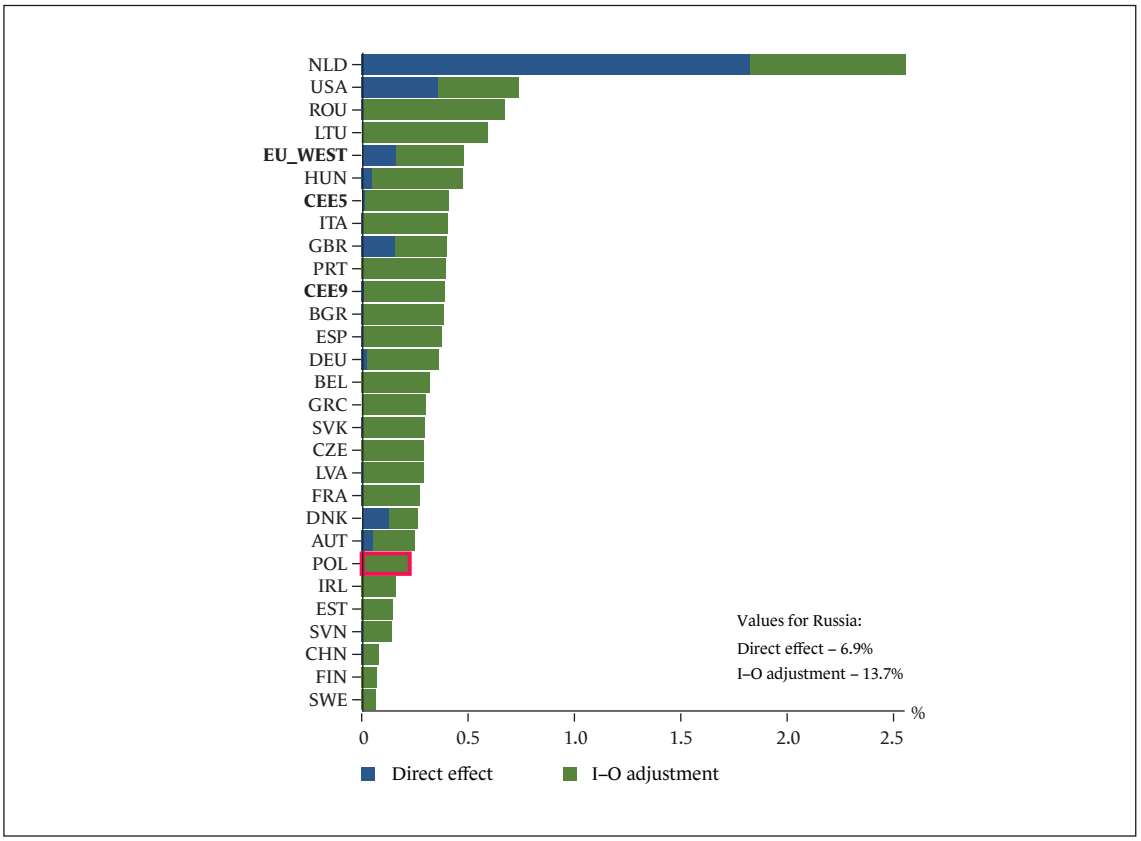
A model of this form allows us to introduce an exogenous shock for any price(s) and determine a vector of prices (or rather production cost indices), taking into account the fact that price increases in one sector translate into price increases in other sectors by affecting their costs, propagating throughout the economic system. The resulting price vector $\left(1+\tau\right)p$ can then be aggregated using arbitrary weights, in particular using the product structure of exports, to obtain an export deflator.

Figure 1
EU gas prices for firms in 2024 (EUR/kWh)



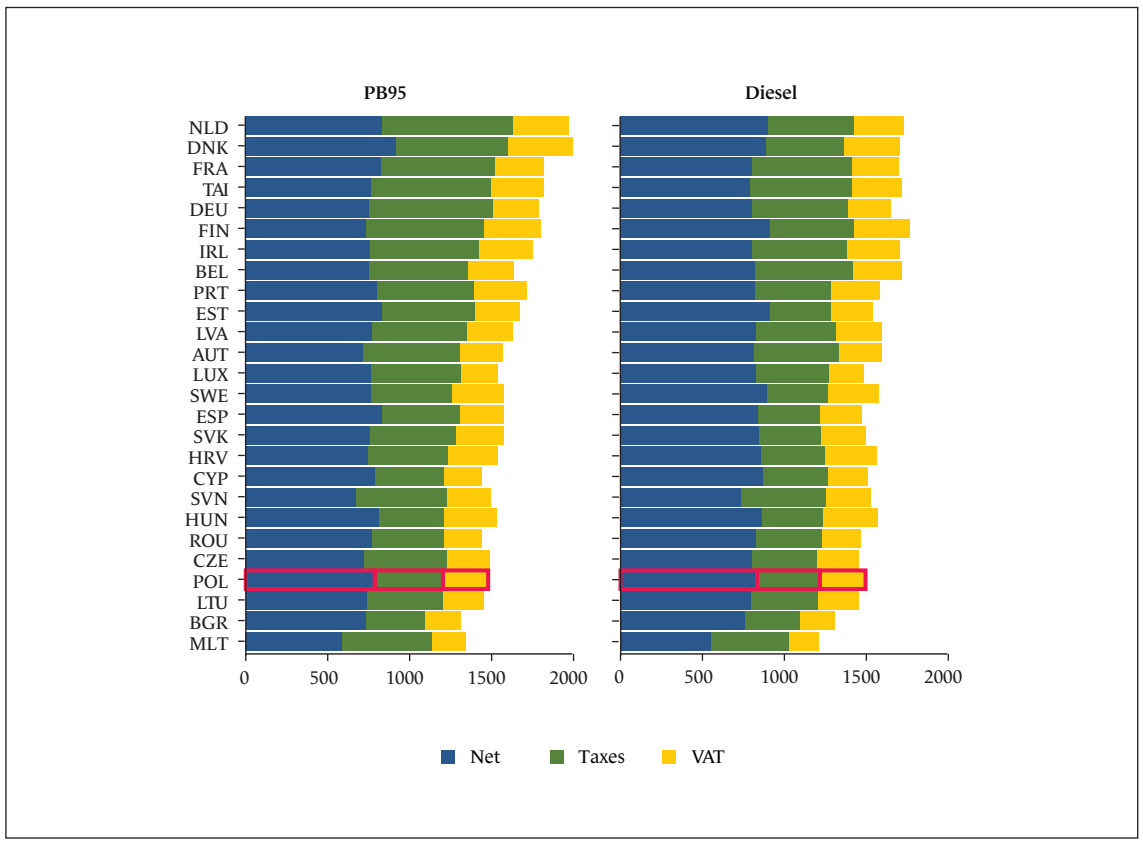
Source: own compilation based on Eurostat.

Figure 2
Export price changes – 100% gas shock



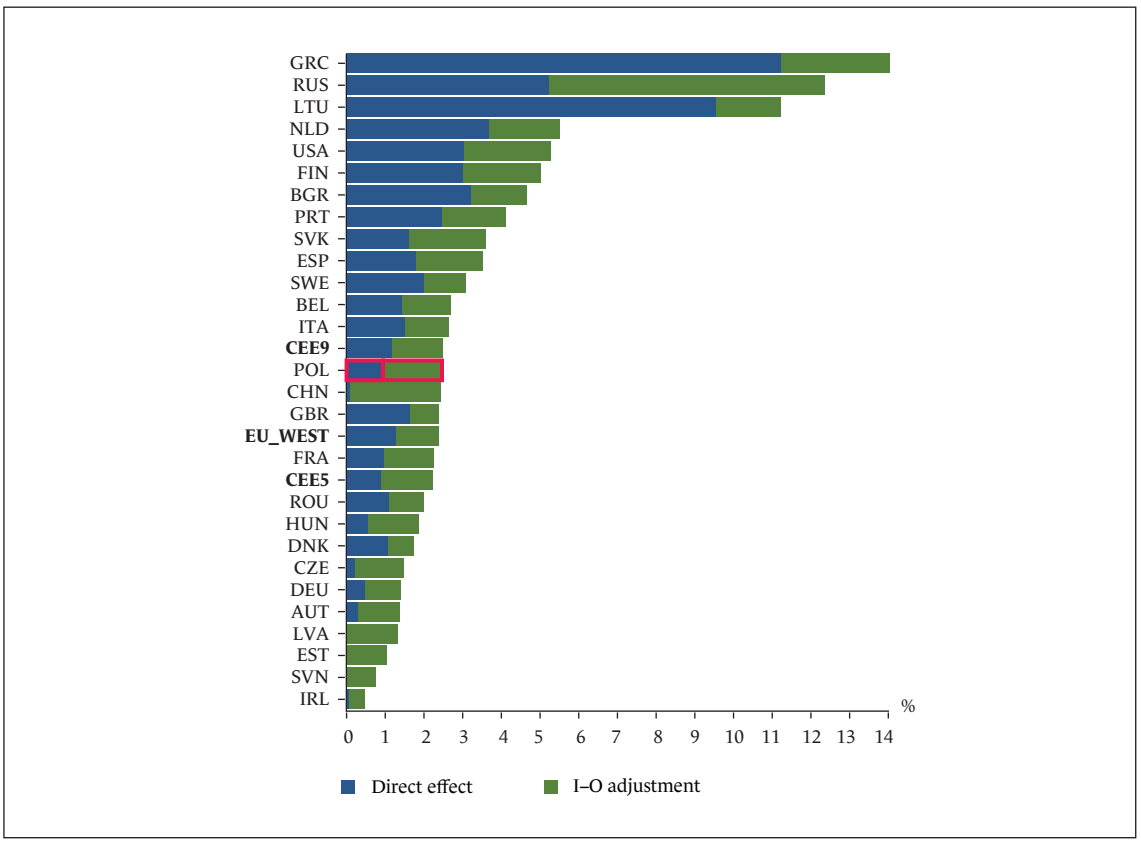
Source: own calculations based on JRC data.

Figure 3
EU average price of gasoline and diesel (EUR/1000 L) in 2024



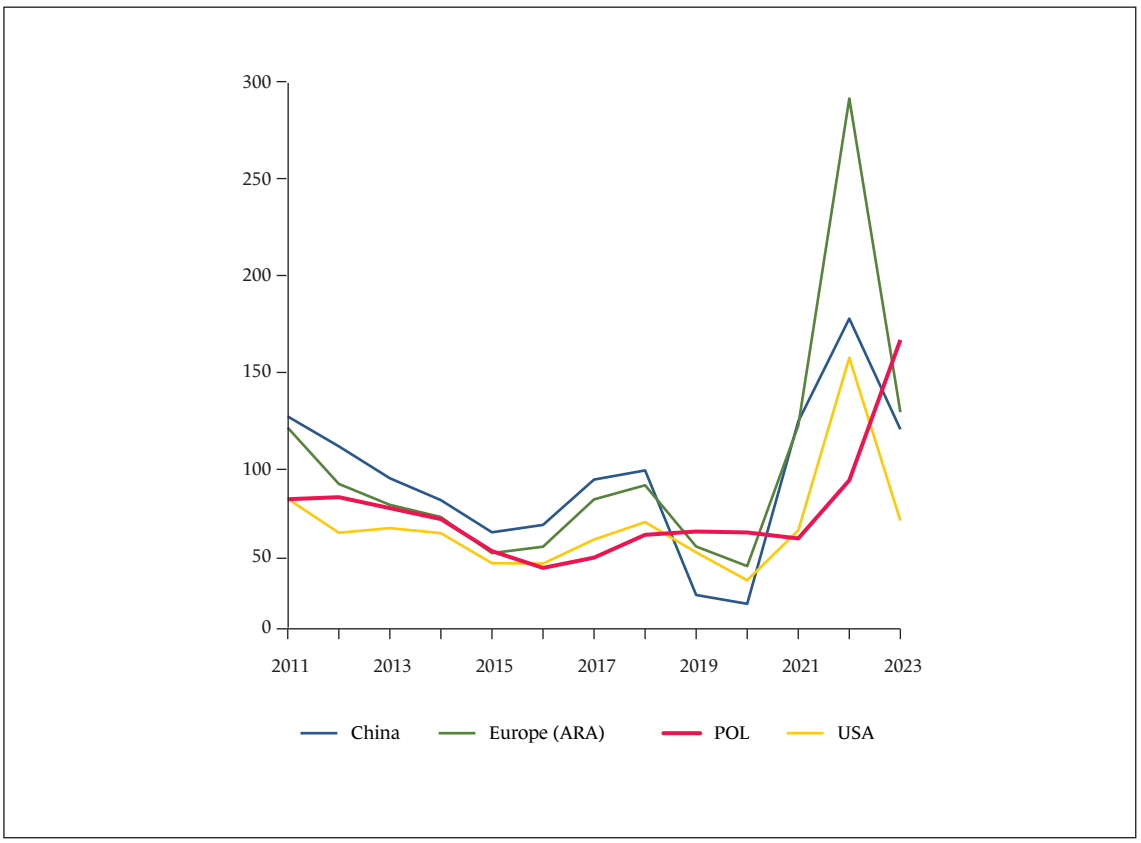
Source: own compilation based on European Commission (Weekly Oil Bulletin).

Figure 4
Export price changes – 100% oil price shock



Source: own calculations based on JRC data.

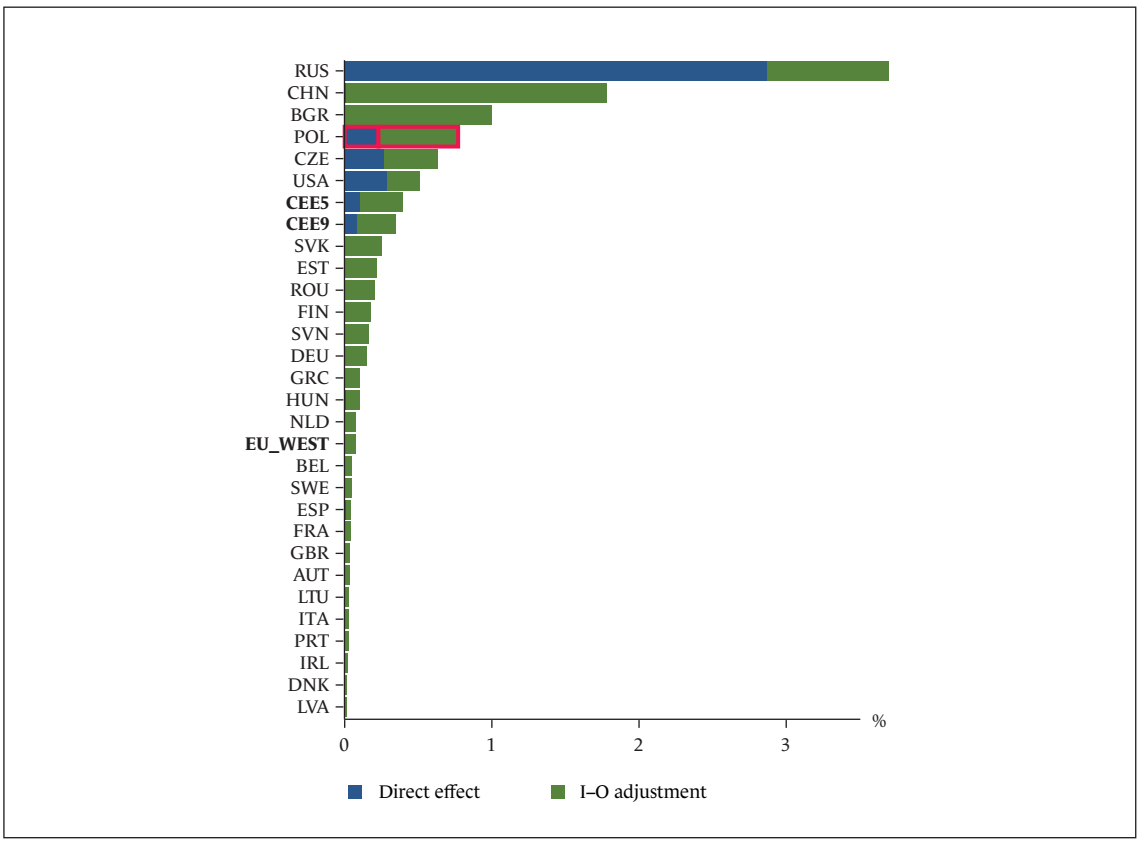
Figure 5
Coal prices in selected areas, USD/ton



Note: Europe refers to the Northwest Europe region and reflects prices in the ARA market. No comparative data is available for the Russian market.

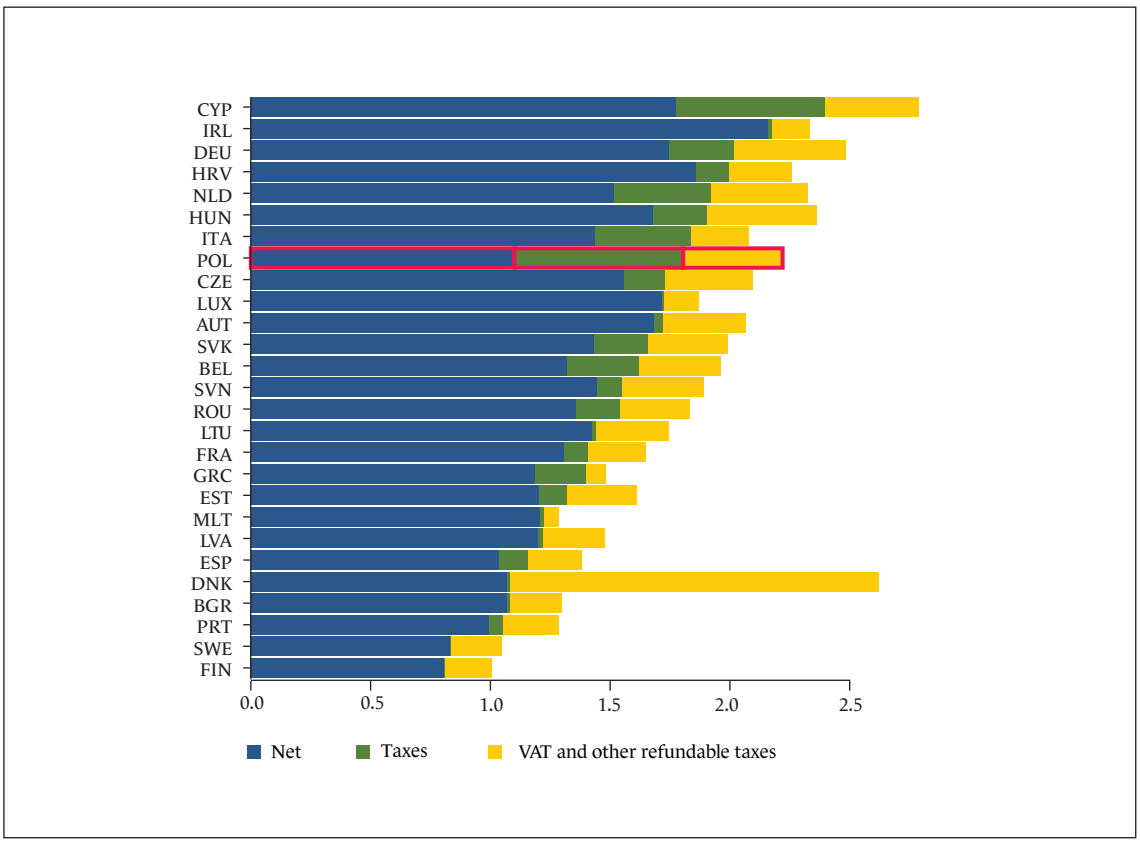
Source: compiled from Statistical Review of World Energy (2024) and calculations based on JRC I–O tables.
For Poland, PSCMI1 coal was considered and converted to USD values.

Figure 6
Export price changes – 100% coal price shock



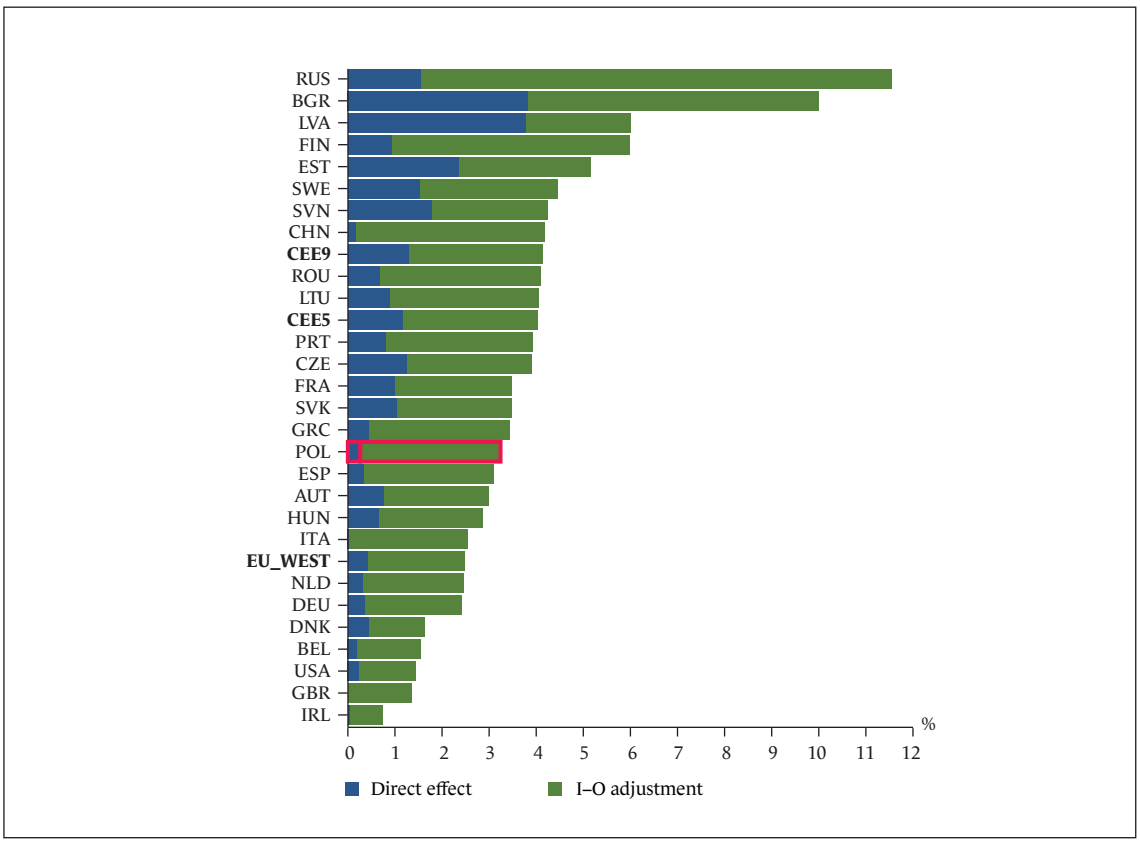
Source: own calculations based on JRC data.

Figure 7
EU electricity prices for firms 2024 (EUR/kWh)



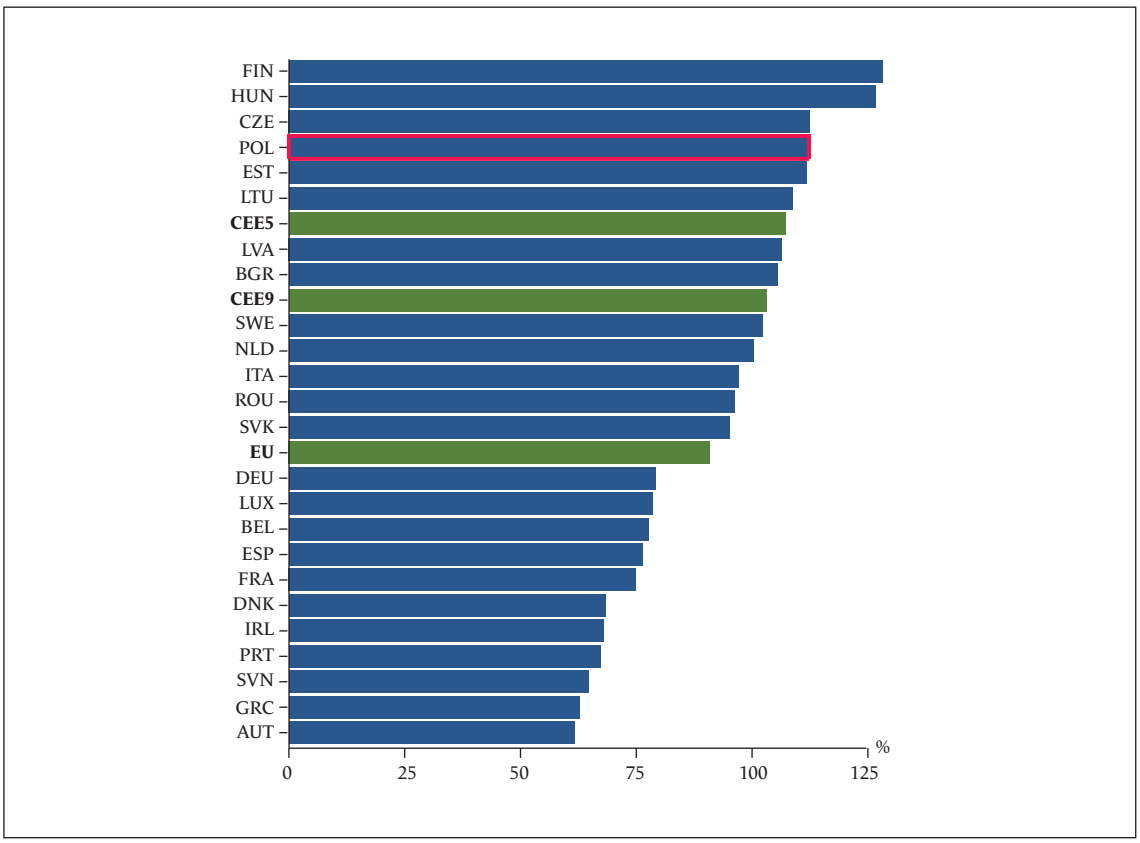
Source: own compilation based on Eurostat.

Figure 8
Export price changes – 100% electricity price shock



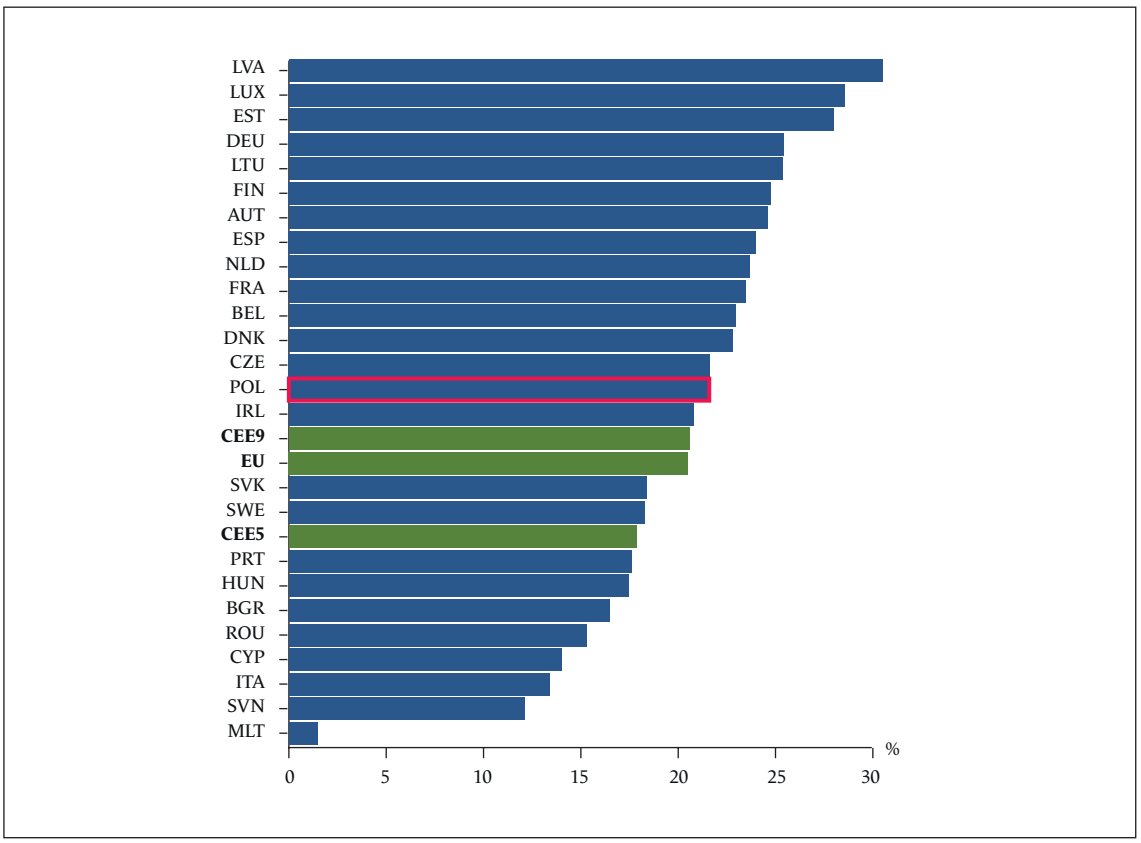
Source: own calculations based JRC data.

Figure 9
Observed price change for gas (average 2020–2024 compared to average 2015–2019)



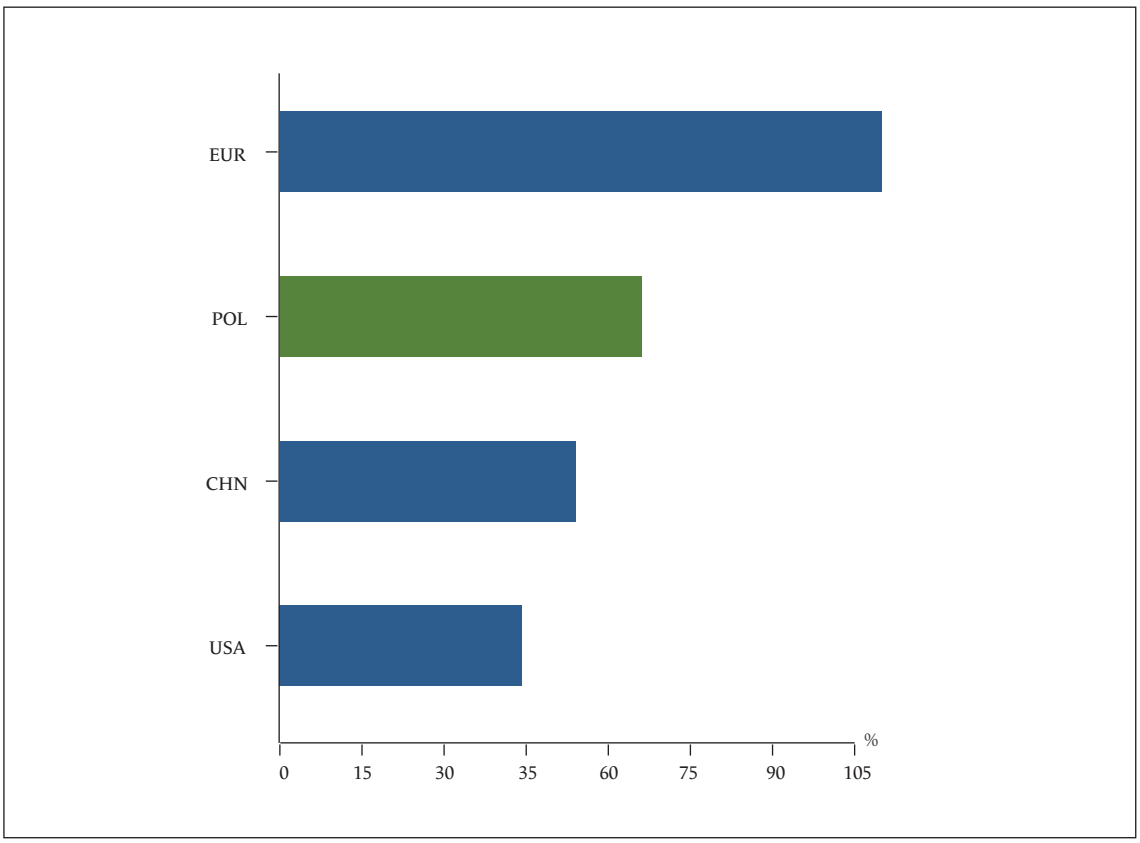
Source: own compilation and calculations based on Eurostat.

Figure 10
Observed price change for oil (average 2020–2024 compared to average 2015–2019)



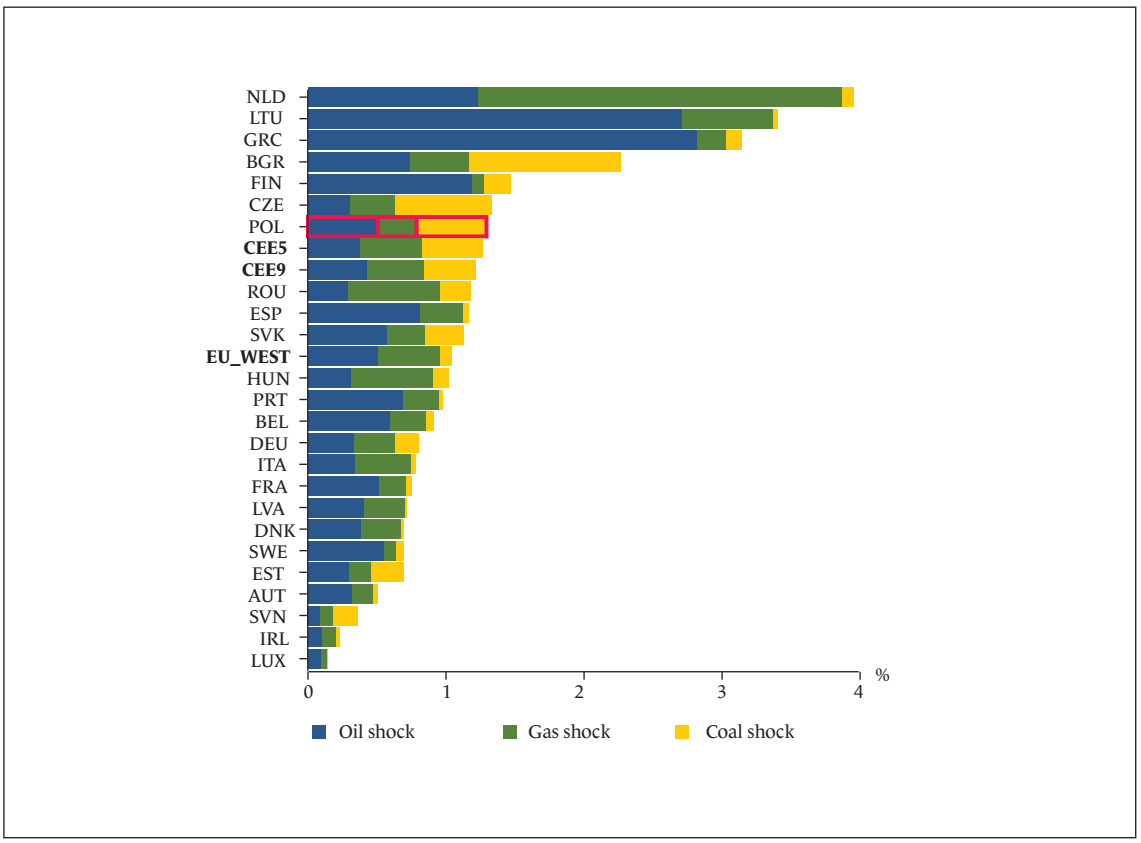
Source: own compilation and calculations based on Eurostat.

Figure 11
Observed price change for coal (average 2020–2024 compared to average 2015–2019)



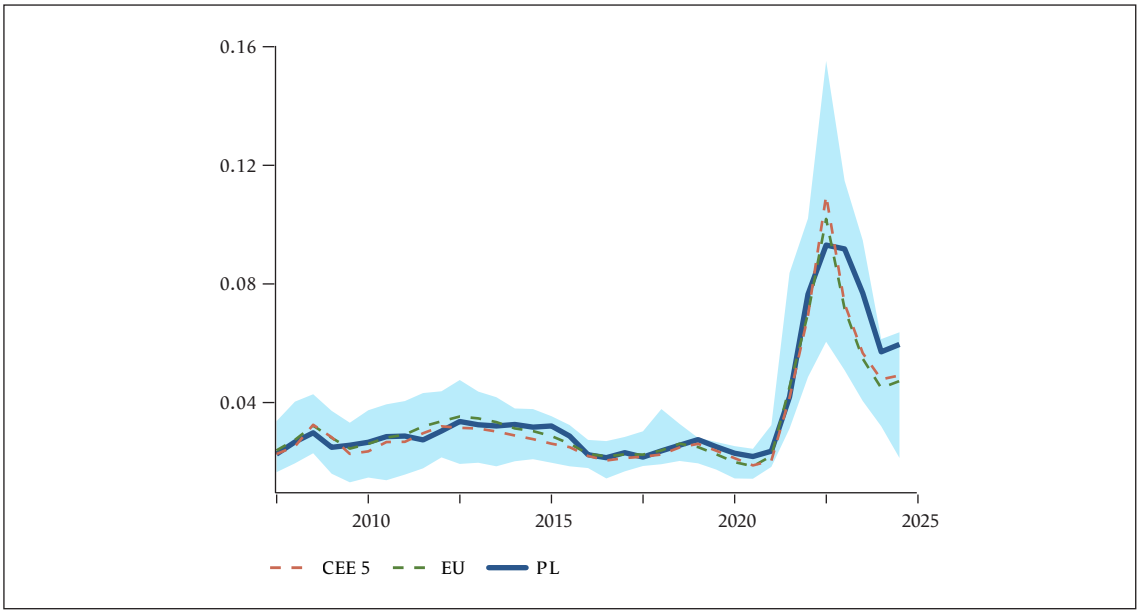
Source: own compilation and calculations based on ARP and Statistical Review of World Energy.

Figure 12
Export price change due to observed price increases of energy carriers



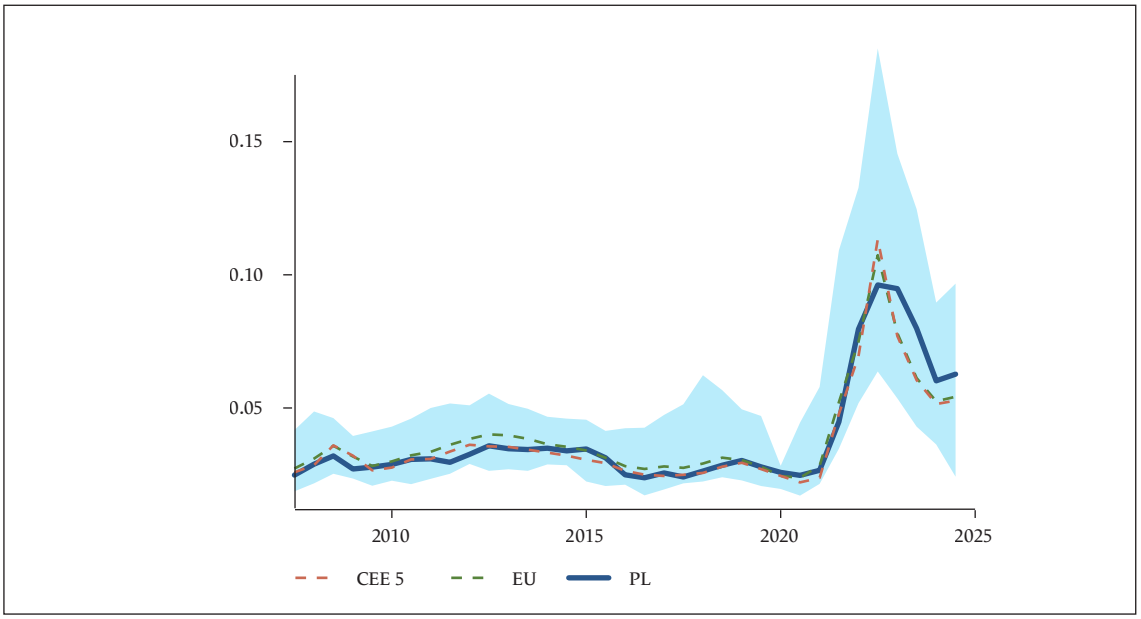
Source: own compilation and calculations based on Eurostat, ARP, Statistical Review of World Energy and JRC data.

Figure 13
EU net gas prices for firms 2007–2024 (EUR/kWh)



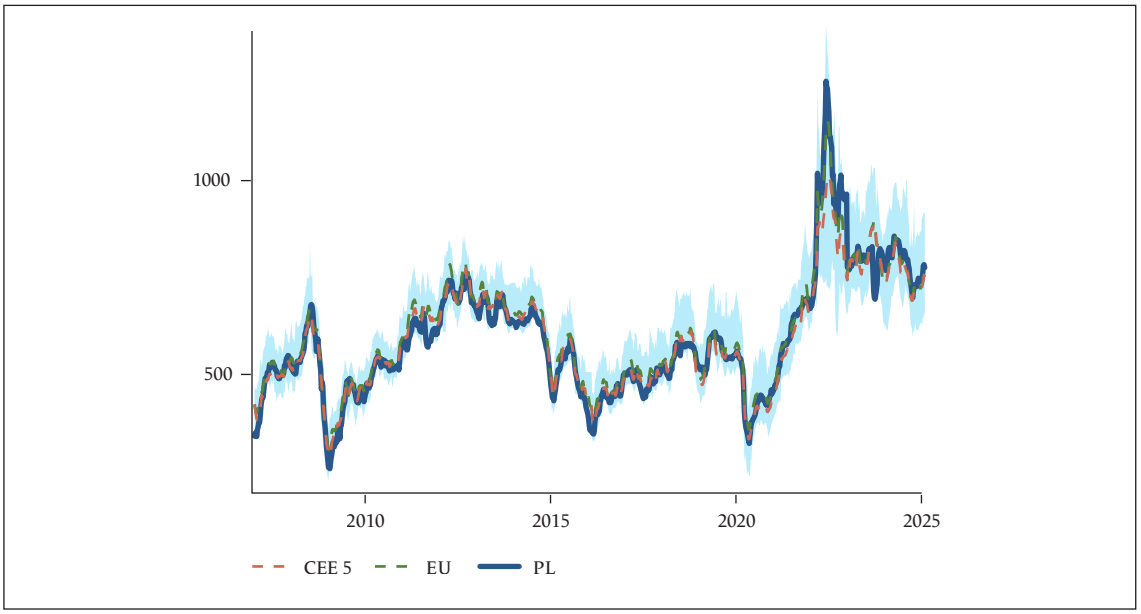
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 14
EU gross gas prices for firms 2007–2024 (EUR/kWh)



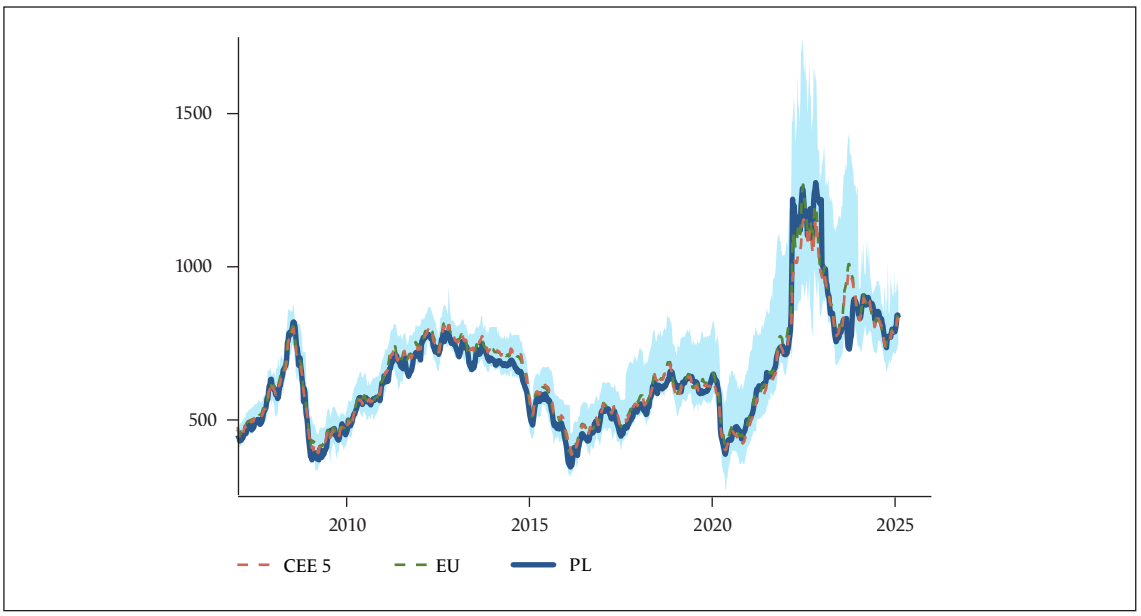
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 15
EU net PB95 prices (EUR/1000 L)



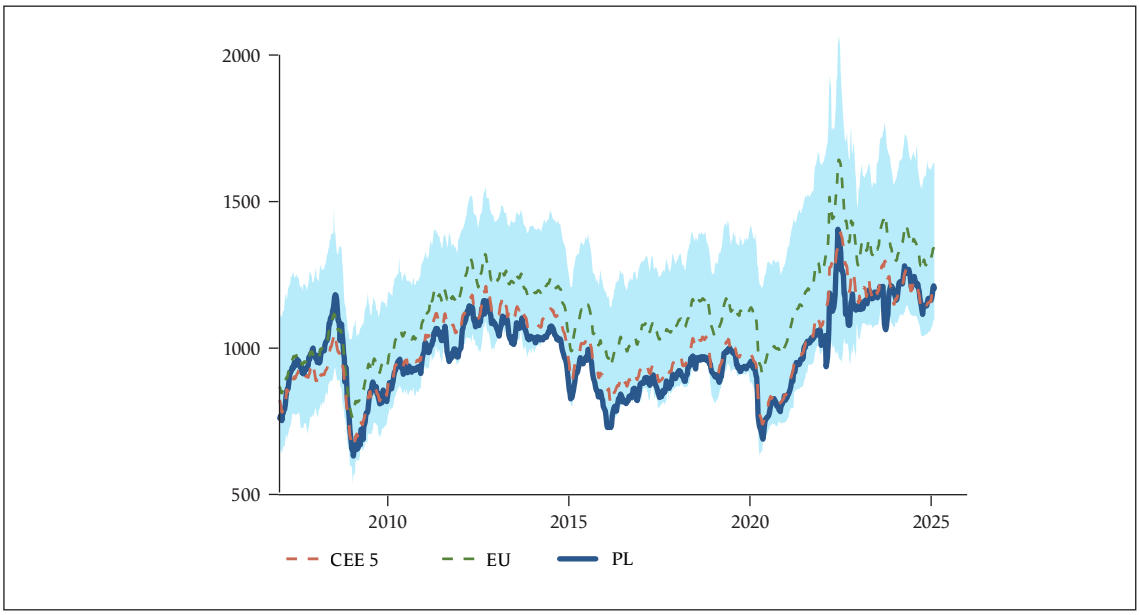
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 16
EU net diesel prices (EUR/1000 L)



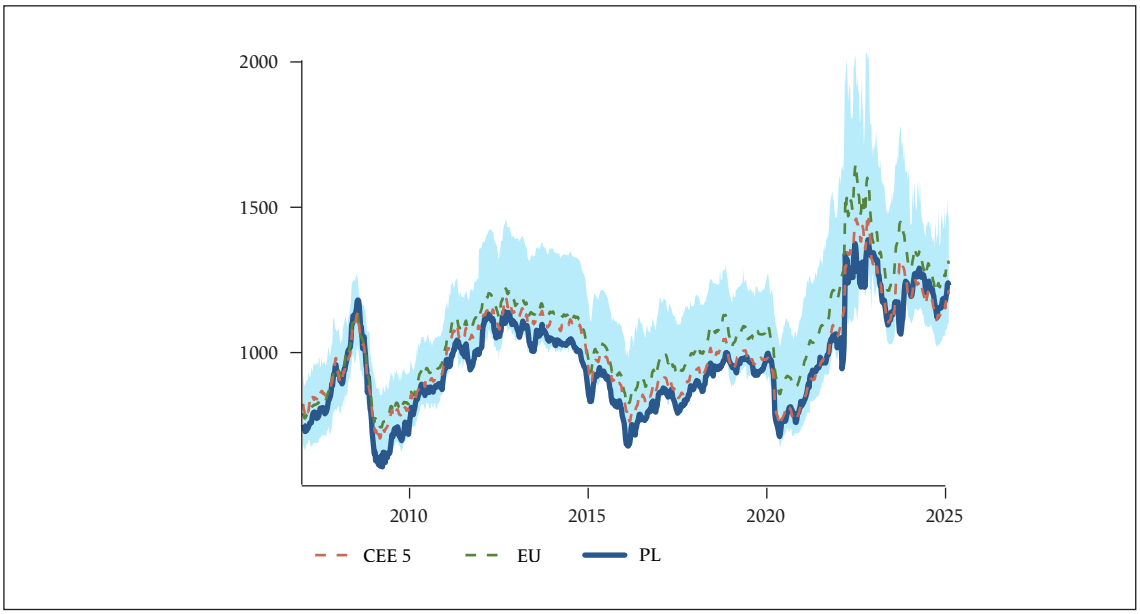
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 17
EU gross PB95 prices (EUR/1000 L)



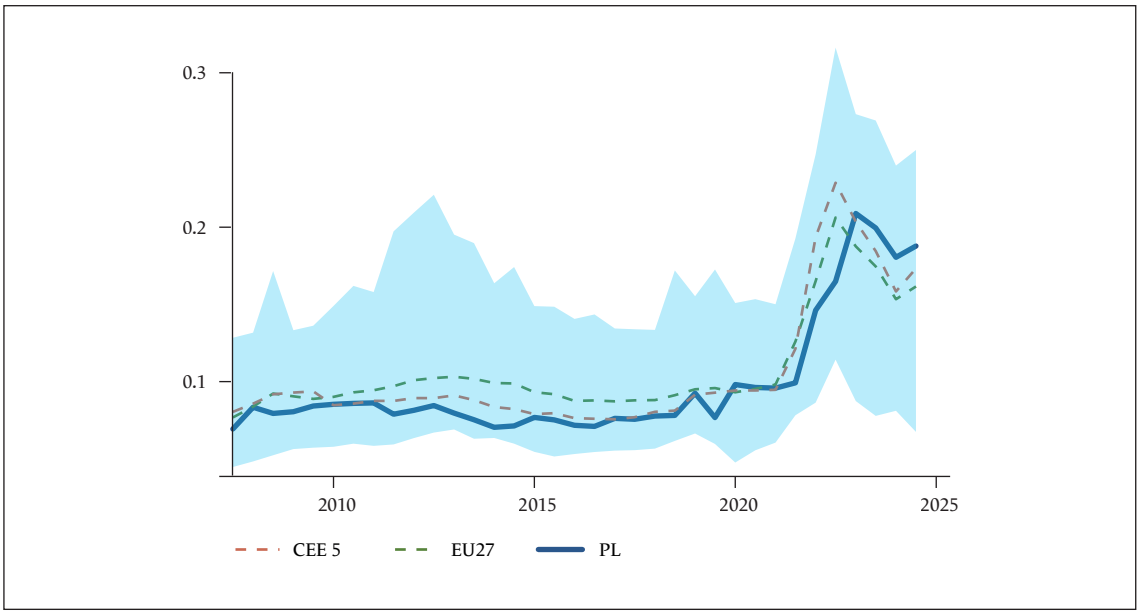
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 18
EU gross diesel prices (EUR/1000 L)



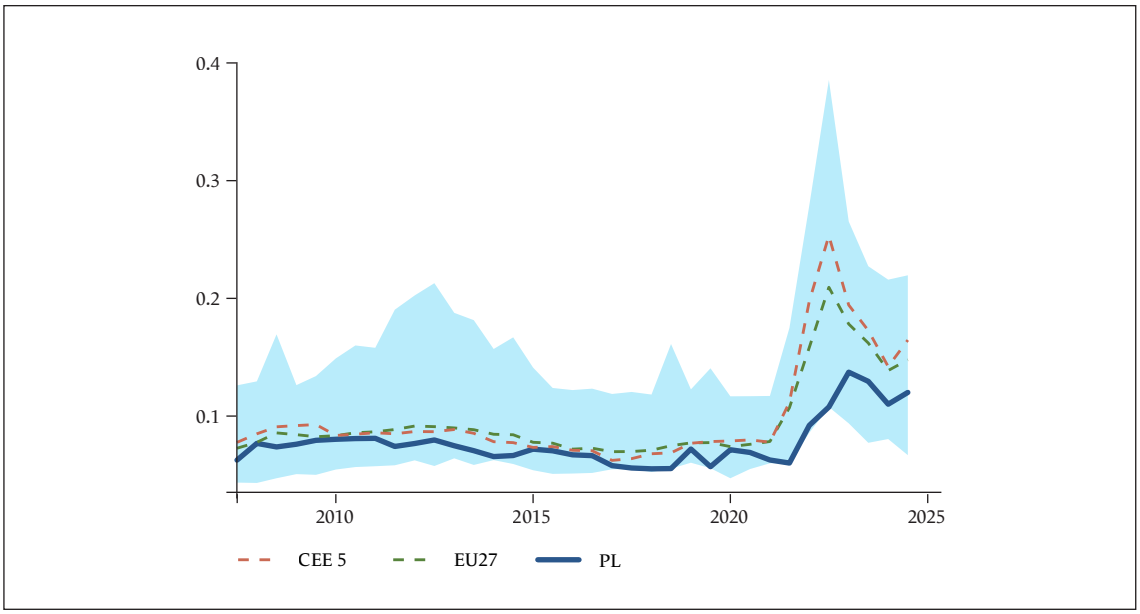
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 19
EU electricity gross prices for firms in 2007–2024 (EUR/kWh)



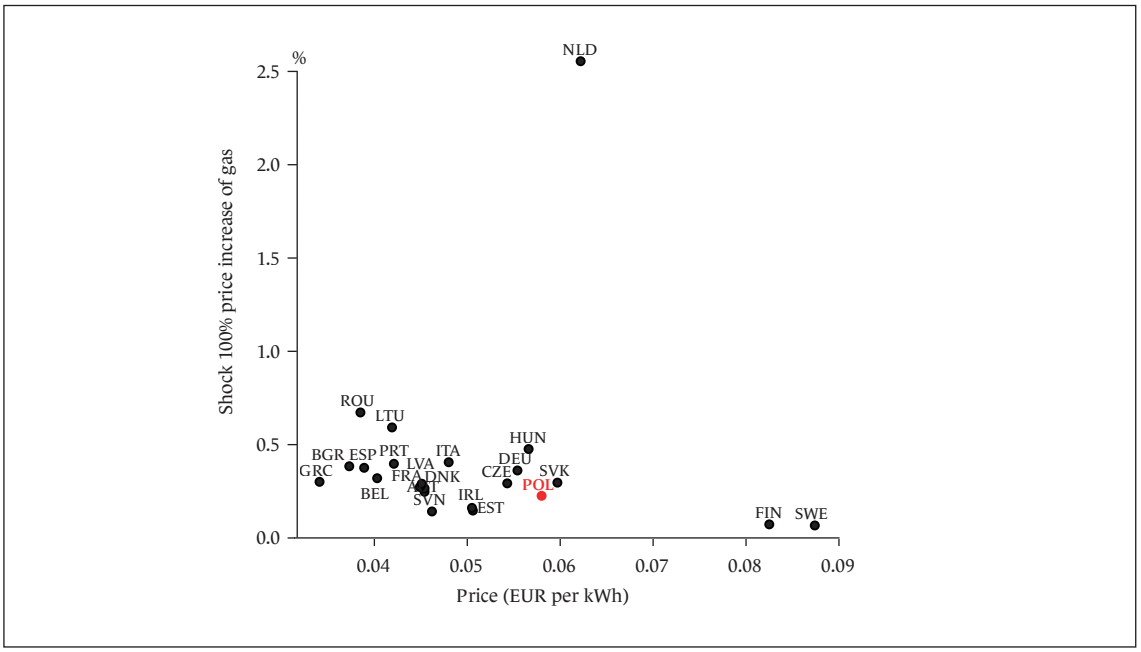
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 20
EU electricity net prices for firms in 2007–2024 (EUR/kWh)



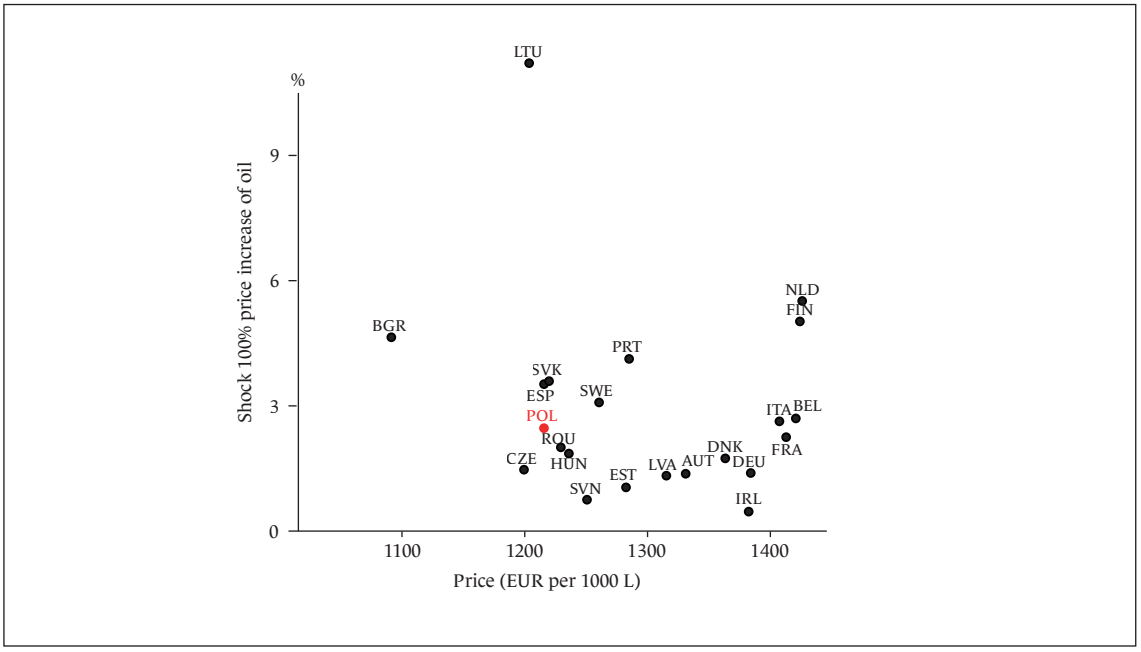
Note: the shaded area in the figures indicates the scale of variation in price levels over the period among EU countries.
Source: Eurostat and own calculations.

Figure 21
Relationship between exporter's price increase (shock 100%) and the observed prices in 2024 – natural gas



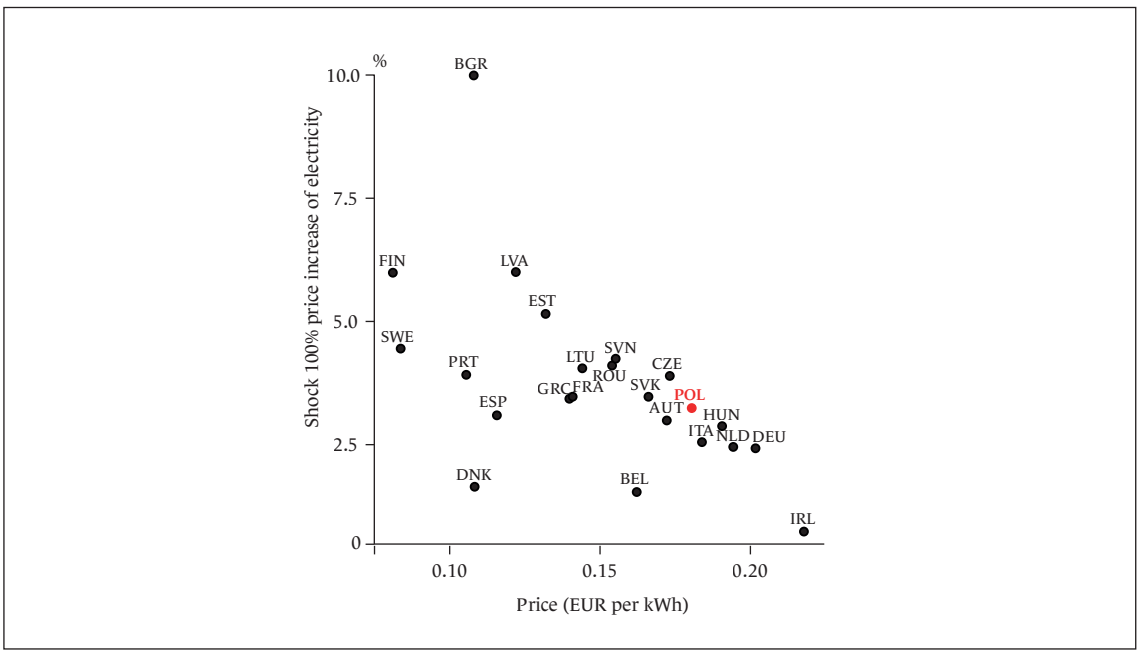
Source: own calculations based on Eurostat data and JRC I-O tables.

Figure 22
Relationship between exporter's price increase (shock 100%) and the observed prices in 2024 – liquid fuels



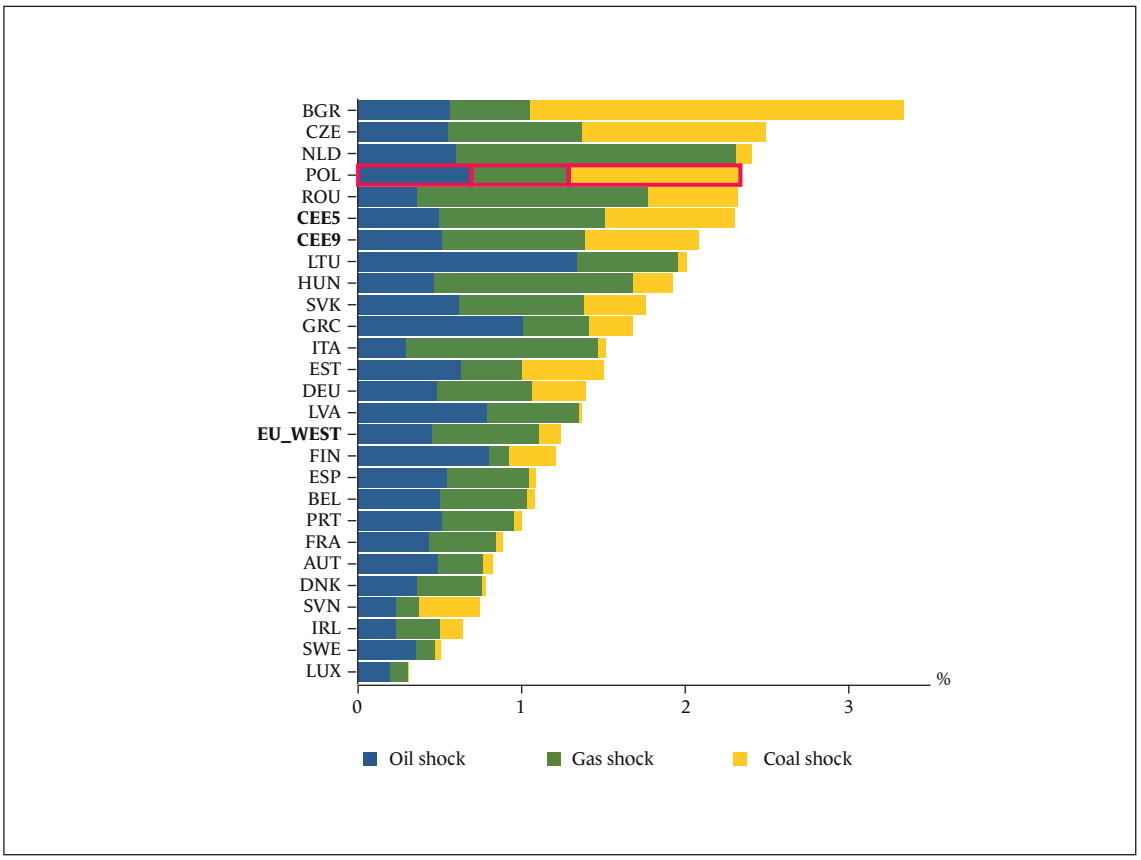
Source: own calculations based on Eurostat data and JRC I-O tables.

Figure 23
Relationship between exporter's price increase (shock 100%) and the observed prices in 2024 – electricity



Source: own calculations based on Eurostat data and JRC I-O tables.

Figure 24
Producer price change due to observed price increases of energy carriers



Source: own compilation and calculations based on Eurostat, ARP, Statistical Review of World Energy and JRC data.

Table 1
Export price changes (producer price changes in case of Global Output weights) due to observed price increases of energy carriers – robustness check according to different calibration variants (in %)

	Baseline	I-O 2025	Global output weights	Brent oil shock
NLD	4.0	4.4	2.4	4.5
LTU	3.4	5.5	2.0	3.9
GRC	3.1	4.9	1.7	4.4
BGR	2.3	2.6	3.3	2.9
FIN	1.5	2.2	1.2	1.7
CZE	1.3	1.5	2.5	1.4
POL	**1.3**	**1.7**	**2.3**	**1.5**
ROU	1.2	1.8	2.3	1.5
ESP	1.2	1.8	1.1	1.4
SVK	1.1	1.6	1.8	1.5
HUN	1.0	1.4	1.9	1.2
PRT	1.0	1.4	1.0	1.5
BEL	0.9	1.4	1.1	1.1
DEU	0.8	1.1	1.4	0.9
ITA	0.8	1.1	1.5	1.2
FRA	0.8	1.0	0.9	0.9
LVA	0.7	1.0	1.4	0.7
DNK	0.7	0.9	0.8	0.8
SWE	0.7	0.9	0.5	1.0
EST	0.7	0.9	1.5	0.7
AUT	0.5	0.8	0.8	0.6
SVN	0.4	0.5	0.7	0.5
IRL	0.2	0.3	0.6	0.3

Note: results are sorted by the baseline column.
Source: own calculations based on JRC (I-O-related) and Reuters (oil prices).

Table 2
Decomposition of export price change due to observed price increases of energy carriers (in %)

	Gas shock	Coal shock	Oil shock	Total
NLD	2.6	0.1	1.2	4.0
LTU	0.7	0.0	2.7	3.4
GRC	0.2	0.1	2.8	3.1
BGR	0.4	1.1	0.7	2.3
FIN	0.1	0.2	1.2	1.5
CZE	0.3	0.7	0.3	1.3
POL	**0.3**	**0.5**	**0.5**	**1.3**
ROU	0.7	0.2	0.3	1.2
ESP	0.3	0.0	0.8	1.2
SVK	0.3	0.3	0.6	1.1
HUN	0.6	0.1	0.3	1.0
PRT	0.3	0.0	0.7	1.0
BEL	0.3	0.1	0.6	0.9
DEU	0.3	0.2	0.3	0.8
ITA	0.4	0.0	0.3	0.8
FRA	0.2	0.0	0.5	0.8
LVA	0.3	0.0	0.4	0.7
DNK	0.3	0.0	0.4	0.7
SWE	0.1	0.1	0.6	0.7
EST	0.2	0.2	0.3	0.7
AUT	0.2	0.0	0.3	0.5
SVN	0.1	0.2	0.1	0.4
IRL	0.1	0.0	0.1	0.2

Source: own compilation and calculations based on Eurostat, ARP, Statistical Review of World Energy and JRC data.

Wpływ cen energii na konkurencyjność gospodarki Polski i wybranych krajów europejskich

Streszczenie

W literaturze przedmiotu badania nad wpływem zmian cen energii na konkurencyjność gospodarek koncentrowały się głównie na efektach makroekonomicznych, takich jak PKB czy inflacja. Wykorzystywano w ich modele ekonometryczne oraz wielosektorowe modele *input–output* i CGE. W artykule przyjmujemy inną perspektywę, analizując wpływ wahań cen energii na ceny eksportowe krajów europejskich, w tym Polski, z zastosowaniem cenowego modelu Leontiefa.

Podstawowym celem badawczym artykułu jest określenie wrażliwości cen eksportowych na zmiany cen gazu, ropy, węgla i energii elektrycznej oraz identyfikacja różnic między krajami. Proponowane w artykule podejście zakłada, że zmiany cen energii mają zróżnicowany wpływ na ceny eksportowe, przy czym największe znaczenie mają ropa i energia elektryczna, natomiast gaz i węgiel wpływają głównie w wybranych sektorach lub krajach o wysokim udziale tych nośników w produkcji.

W przeprowadzonej analizie zastosowano cenowy model Leontiefa, który pozwala uwzględnić zarówno bezpośrednie, jak i pośrednie skutki wzrostu cen energii, wynikające z powiązań między sektorami. Do kalibracji modelu wykorzystano wielosektorowe tabele *input–output* (2020) przygotowane przez Joint Research Center Komisji Europejskiej dla krajów europejskich oraz wybranych krajów pozaeuropejskich, z dokładnym rozbiciem sektorów energetycznych. Agregacji cen sektorowych do poziomu cen eksportowych dokonano przy użyciu wag eksportowych.

Wyniki pokazują, że największy wpływ na ceny eksportowe mają wahania cen ropy oraz energii elektrycznej; przy hipotetycznym 100-procentowym wzroście cen ropy ceny eksportowe wzrosły o ponad 2% w CEE9 i EU WEST (Polska – 2,5%). W przypadku gazu wpływ był znacznie mniejszy (do 0,8%, w Polsce 0,2%), a dla węgla – minimalny, z wyjątkiem krajów o wysokiej ekspozycji na węgiel w miksie energetycznym (Polska, Czechy, Bułgaria). Analiza historycznych zmian cen w latach 2015–2019 i 2020–2024 wykazała istotne zróżnicowanie między krajami: najwyższy wzrost cen eksportowych odnotowano w Holandii, na Litwie i w Grecji (ponad 3%), najniższy w Austrii, Słowenii, Irlandii i Luksemburgu (poniżej 0,5%). W Polsce wzrost cen eksportowych wyniósł 1,3%, nieco powyżej średniej krajów CEE i powyżej średniej EU WEST. W większości państw zmiany cen eksportowych były głównie efektem wahań cen ropy i gazu, natomiast w niektórych krajach (Litwa, Grecja, Finlandia, Hiszpania, Francja, Szwecja) największy wpływ miały zmiany cen ropy, mimo umiarkowanego wzrostu jej ceny. W Polsce wraz z Czechami, Bułgarią, Słowacją i Słowenią zmiany cen węgla miały zauważalny wpływ na ceny eksportowe.

Ograniczeniem badania jest przyjęcie uproszczonego mechanizmu szoków cenowych, zastosowanie hipotetycznych 100-procentowych wzrostów cen oraz ograniczona dostępność porównywalnych danych o cenach węgla. Wyniki należy interpretować w kontekście przyjętej metodyki i założeń modelu Leontiefa, który uwzględnia jedynie efekty cenowe i nie obejmuje ilościowych zmian popytu czy inwestycji w dłuższym okresie.

Słowa kluczowe: szoki energetyczne, cenowy efekt przeniesienia, konkurencyjność cenowa, cenowy model Leontiefa