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Energy Subsidies and their Implications for CO_2 Emissions in the Visegrad Group Countries

Edward Molendowski https://orcid.org/0000-0003-0803-1592
Ph.D., Professor, WSB University, Faculty of Applied Sciences, Dąbrowa Górnicza, Poland
e-mail: edward.molendowski@wsb.edu.pl

Agnieszka Pach-Gurgul https://orcid.org/0000-0003-1917-4679
Ph.D., Assistant Professor, Cracow University of Economics, Department of International Economics, Cracow Poland, e-mail: apach@uek.krakow.pl

Marta Ulbrych https://orcid.org/0000-0003-3886-371X
Ph.D., Assistant Professor, Cracow University of Economics, Department of International Economics, Cracow Poland, e-mail: ulbrychm@uek.krakow.pl

Abstract

The aim of the article is to present a review of the literature on energy subsidies and the scale and structure of subsidies for energy production in the Visegrad Group countries. It also presents the most important results of an investigation into the relationship and impact of fossil fuel subsidies on CO_2 emissions based on a linear regression model. Due to the availability of comparable statistical data, the survey was limited to the period 2015–2020. The analysis does not provide a clear confirmation of the negative impact of the amount of subsidies (from the current or previous year) on the level of CO_2 emissions.

Keywords: CO_2, fossil fuel, subsidies, V4 countries

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Introduction

Government subsidies for energy consumption and production, including fossil fuels – and the social, environmental, and fiscal consequences of fossil fuels – have been analysed in many economic studies. By affecting the final price levels for producers and consumers, such subsidies cause the simultaneous overproduction and increased consumption of energy products relative to the market situation without such subsidies. The debate on subsidising fossil fuels and electricity production intensified after the 2009 G20 Pittsburgh Summit. The leaders reiterated the commitment to "Rationalize and phase out over the medium-term inefficient fossil fuel subsidies that encourage wasteful consumption. As we do that, we recognize the importance of providing those in need with essential energy services, including through the use of targeted cash transfers and other appropriate mechanisms. This reform will not apply to our support for clean energy, renewables, and technologies that dramatically reduce greenhouse gas emissions" (G20 Information Centre 2009). Since then, the reduction and reform of economically inefficient and environmentally harmful fossil fuel subsidies have become a major issue on the political agenda of many governments worldwide. It was also reflected in the plan of action adopted by the UN in 2015, *Transforming our world: the 2030 Agenda for Sustainable Development,* where, among 17 Sustainable Development Goals, Goal 12c stated: "Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts" (United Nations 2015).

In the context of the international debate on climate change and the transition to a low-emissions economy, attention must be drawn to the efforts made by the European Union (EU), where decarbonisation and the Climate Policy are becoming more important in the energy policy. The ultimate goal is to achieve climate neutrality in the aspect of CO_2 emissions by 2050 through renewable energy sources, energy efficiency, and reduced greenhouse gas emissions. Furthermore, the European Commission (EC) has undertaken to phase out inefficient fossil fuel subsidies by 2025, with the first annual monitoring report, *Member States' progress towards phasing out energy and more specifically, fossil fuel subsidies in the EU*, published in 2020, according to the requirement of the *Regulation on the Governance of the Energy Union and Climate Action* (European Commission 2020a). Nevertheless, Member States continue subsidising energy sources, explaining that such measures are necessary for the transition towards a low-emissions economy and to improve the security of supplies, or price competitiveness, which is often contrary to the adopted climate goals.

Due to the high degree of dependence on energy resources imported from Russia, questions about the pace of energy transformation and the issue of the EU's energy security have become particularly important following Russian aggression on Ukraine. Russia is the country of origin of 25% of oil, 45% of natural gas, and 44% of hard coal imported by the EU. Central and Eastern European countries are more dependent on Russian oil than Western European countries (Lipiński, Maj, and Miniszewski 2022). Apart from diversifying resource supplies and further developing renewable energy sources, it may be necessary to strengthen the EU's strategic security by reducing the demand for energy by changing consumer behaviour.

Although the transition to low-emission energy sources has been the subject of many studies, energy subsidies are not widely described in the literature on the subject. The article fills this research gap. It is structured as follows. First, there is a literature review, and then the scale and structure of energy production subsidies in the Visegrad Group (V4)[1] are presented. Finally, an attempt will be made to identify the dependencies and impact of fossil fuel subsidies on CO_2 emissions based on the linear regression model. Due to the availability of comparable statistical data, the research was limited to the period 2015–2020, with the analysis performed using R software, version 4.1.2.

Literature review

For many years, state intervention has been visible in the energy sector. Governments used subsidies to improve the security of supplies, reduce air pollution and greenhouse gas emissions, increase competition, and ensure social protection and employment security (Koplow 1996). However, opinions on the efficiency of those measures vary (OECD & IEA 2021). Furthermore, political priorities and technological capacities change over time. General energy subsidies should meet fundamental social, economic, and environmental goals. Lower energy prices allow low-income households to use various electrical devices and appliances to heat their homes. Thus, they achieve a higher living standard, which would be impossible without such support. Support for producers aims to reduce energy generation costs, help investments, and stimulate production capacity. It can also help them develop new types of energy media, including renewable energy sources.

The state also supports producers that use natural energy for manufacturing technologies. Subsidies for energy and fuel production often also serve to keep jobs and reduce unemployment, particularly in the coal mining sector in many countries rich in this resource. Removing subsidies for coal mining would often mean shutting down unprofitable mines, the loss of jobs, and the deterioration of the trade balance as a result of increased imports. Various forms of subsidies for producers and investors support the search for new energy sources and the development of production, particularly in the early phase of implementation. It also serves to improve the natural environment by encouraging energy production that involves lower emissions of harmful substances into the air.

1 An informal regional cooperation between the Czech Republic, Hungary, Poland, and Slovakia.

Governments also tend to support the development of transmission and transport infrastructure, as well as measures related to liquidating old and inefficient production plants and waste management. Significant state funds are also devoted to energy consumers to encourage them to undertake actions aimed at energy savings and lower fuel consumption. However, energy subsidies often do not allow the intended social and economic goals to be achieved effectively. Subsidies for household energy consumption result in higher-income consumers, who consume more energy than the average household, being the main beneficiaries. Consequently, although higher-income households consume more energy in absolute terms, the share of energy-related expenditures in total expenditures is higher in poorer households. Subsidies for producers, in turn, are not favourable to reducing energy-consuming production and replacing old plant with new low-energy equipment.

International discussion still lacks a consistent universal definition of energy subsidies or a harmonised reporting mechanism (Koplow 1993; Myers and Kent 2001). Budget subsidies are transfers that appear in domestic accounts as governmental expenditures. Examples include cash transfers to energy producers, consumers, and similar entities, as well as low-interest loans or loans with interest rates reduced by the government. Off-budget subsidies, in turn, include tax reliefs and exemptions, preferential market access, regulatory support mechanisms, and preferential access to natural resources (van Beers and Moor 1999; van Beers et al. 2007).

By regulating domestic prices and keeping them below global market prices, governments can support the consumption of particular energy resources. They can also decide to subsidise production, for example, by imposing minimum prices above the market level. In such a case, producers increase the supply and accelerate the shortage of particular energy resources while public budgets are used to cover the surpluses. Both types of political interventions above can exist simultaneously and form a thick network of distortions causing significant fiscal drainage. Through overproduction or excess consumption, subsidies for both producers and consumers may degrade the natural environment (Moor and Calamai 1997; Moor 2001).

Various institutions are also involved in the classification, cataloguing, and analysis of energy subsidies, and definitions of energy subsidies applied by the various organisations to estimate the scale materially differ from one another. Non-uniform definitions thus lead to large differences in the estimated volumes of support (IRENA 2020).

The International Energy Agency (IEA) defines energy subsidies as "any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers" (IEA 2014). The subsidy amount is the difference between the reference price and the price paid by end customers. If it is positive, the product is considered subsidised. For energy importers, the reference price is deemed as the import price paid by the nearest international energy hub, plus the costs of transport and distribution plus VAT. For energy exporters, it is defined as the export price less costs of transport and distribution plus VAT. Such an approach is questioned by many energy exporters and by OPEC, who believe that the reference price should be determined based on generation costs, not the export price (IEA, OPEC, OECD and World Bank 2010).

The OECD defines support as a measure "that provides a benefit or preference for fossil-fuel production or consumption" (OECD 2015). By affecting the final price levels for producers and consumers, energy subsidies cause simultaneous overproduction and excessive consumption of energy products relative to the market situation in the absence of such subsidies. The final result depends on price-related factors of the flexibility of supply and demand for particular energy products. The definition of support applied by the OECD is broad. It covers all forms of budgetary support, including direct transfers and tax reliefs or exemptions that provide benefits or preference for fossil-fuel production or consumption, both on absolute terms and compared to other types of activities or products.

The financial support covered by the OECD listing creates a burden for governmental budgets in the form of increased expenditures or decreased income. The listing does not cover most subsidies for consumption, which is the prevailing form of energy subsidy in developing countries. The OECD has identified over 550 governmental policy measures applied by its members that have been considered fossil fuel support. The volume of energy subsidies estimated by the OECD is the lowest among all international institutions that deal with estimation, which results from the adopted definition. This is because listings drafted by the OECD cover some sorts of funds (not covered by estimates by other organisations) that do not affect consumption price levels, such as benefits for low-income households, benefits for the liquidation of old plants generating energy products, or support of research and development activities (OECD 1997; 1998).

The International Monetary Fund (IMF) applies a more complex definition of energy subsidies. It differentiates between subsidies for producers and consumers, as well as pre-tax and post-tax subsidies. The definition of pre-tax subsidies is comparable with the one applied by the IEA. We deal with consumption subsidies if the price paid by consumer companies (supplier consumption) or households (end-customer consumption) is lower than the costs of generation, transport, and distribution. On the other hand, we deal with production subsidies when the selling price is higher than the costs, plus transport and distribution margins. In international trading, the reference price level is formed by international market prices plus the costs of transport and distribution. For energy products traded domestically, the reference price is adopted at a level that covers generation costs (Clements et al. 2013).

According to the IMF methodology, pre-tax energy subsidies correspond to the definition adopted by IEA; namely, they are the difference between the international market prices and the prices paid by end customers. Post-tax energy subsidies account for external costs that can be attributed to fossil fuel consumption, such as global warming and pollution, as well as its negative impact on human health, the degradation of the environment, and traffic intensity. Such phenomena negatively affect the quality of life and are not accounted for in production costs. However, they generate social costs and require various actions on the part of governments. Such social costs are referred to as "post-tax subsidies" or "hidden energy subsidies." While pre-tax subsidies are popular mainly in developing countries, post-tax subsidies occur on a large scale in both developing and developed countries. Listings of energy subsidies drafted by the IMF are the most complete and cover the greatest number of countries compared to listings by other international institutions.

As already mentioned, comparing energy subsidies is difficult as each institution follows its own calculation methodology. Estimates of energy subsidy values differ considerably depending on the analysing institution and the adopted definition of subsidies. Some institutions apply an overly broad definition, including popular instruments such as accelerated depreciation or reduced VAT rates. The diversity of published statistics is not, however, detrimental to the importance of the global issue of vastly applied energy subsidies. Through excessive consumption of energy products, such subsidies negatively affect the global climate and human health. However, the subsidies can also positively affect the development of new technologies that promote energy generation from renewable resources. Public aid allows the implementation of projects that would be impossible in market conditions. It supports the achievement of strategic goals, such as reducing harmful greenhouse gas emissions.

Energy subsidy statistics prepared by various international organisations are not always continuous. The high labour involved in compiling the data means that the statistics are often published with a significant delay. Additionally, they are not always unavailable for all years, sometimes provided biannually (Taylor 2020).

Recently, various international institutions and scientists from many research centres have analysed the scale and effects of subsidising energy products, in particular, fossil fuels. This is related to measures to reduce global CO_2 emissions and mitigate negative climate change. Research on subsidising fossil fuel and electricity generation intensified after the Pittsburgh G20 Summit in September 2009. All measures in this area accelerated after 2015 and the global adoption of the main assumption of the Paris Agreement, i.e., limiting global warming to "well below 2°C."

Encouraged by the ambitious commitment of the Paris Agreement, the EU decided to be even more active. As early as November 2018, the EC presented its own vision of a climate-neutral EU while analysing all the major sectors, particularly the energy sector, and possible transformation paths. The transition from a 20% reduction in CO_2 emissions to be achieved by 2020 under the energy and climate package from 2008 to an almost complete reduction has become the main challenge for the EU countries. It means a reduction of approximately 114–157 Mt CO_2 emissions each year.

In 2019, the European Council appeared to make more of an effort to fight climate change, addressing the Commission to accelerate works on the EU's climate neutrality based on its international commitments under the Paris Agreement (European Commission 2019). On 1 December 2019, the EC published a communication on the *European Green Deal*. The proposed EU growth strategy should transform the EU into a climate-neutral, just, and prosperous society with a modern, resource-efficient, and competitive economy (European Commission 2020a). The EU's new, very climate-oriented goals focused principally on energy transformation. Therefore, it was agreed that fossil fuel subsidies must be subject to strict control. On the other hand, green subsidies, namely benefits aimed at developing the industry, promoting the consumption of clean types of energy, limiting the consumption of traditional fossil fuels, and counteracting the unfavourable effects of climate change, should function as a tool to transform the energy sector.

In 2020, the EC published its first annual monitoring report of subsidies, "Member States' progress towards phasing out energy and more specifically, fossil fuel subsidies in the EU" (European Commission 2020a).

The recently adopted European Climate Law (European Parliament 2021) cements Europe's goal to become an emission-free continent by 2050, conforming to the goals of the Paris Agreement. According to the new regulation, further efforts are required to ensure a socially fair phasing out of environmentally harmful energy subsidies, in particular, fossil fuels, which are contrary to the goal. Furthermore, the G7 leaders, including EU leaders, committed to phasing out direct governmental support for energy-intensive fossil fuels (G7 2021). The proposal regarding the Revision of the Energy Taxation Directive (Council Directive 2021) supports phasing out obsolete tax breaks and incentives for fossil fuel use while promoting cleaner fuels and supporting the achievement of the EU's ambitious targets for reducing greenhouse gas emissions.

Type and size of energy subsidies in the EU

According to the Regulation on the *Governance of the Energy Union and Climate Action* (SWD(2019) 212 final), the EC drafts annual monitoring reports on Member States' progress towards phasing out fossil fuel subsidies. The first report was published in 2020 and covers the period of 2015–2019 (COM(2020) 950 final). The report relies on direct data collected from Member State sources and the information contained in the National Energy and Climate Plans (NECPs). Our analysis uses the report from 2021 (COM(2021) 950 final). However, some data aggregated for 2020 require confirmation and, additionally, that year was special due to the supply and demand shock caused by the COVID–19 pandemic. Therefore, it was decided that 2019 should serve as the principal point of reference to assure a fuller and more reliable image.

Although in 2020, renewable energy sources exceeded fossil fuels in the EU's energy mix for the first time (38% electricity, 37% fossil fuels, and 25% nuclear energy), Member States still spent 56 billion euros on fossil fuel subsidies in 2019, with 15 Member States spending more on fossil fuels than on renewable energy sources (RES). Analyzing the evolution of energy subsidies in the EU points to financial support in 2019 totalling 176 billion euros. In 2020, the total energy subsidy in the EU remained stable at 177 billion Euros. Subsidies on measures related to energy efficiency, however, continued to grow (by 5%) compared to 2019. Fossil fuel subsidies in 2019 totalled 0.4% of GDP on average, although there are clear differences regarding total subsidy amount vs GDP. The highest expenditures on fossil fuels vs GDP were recorded for Hungary (1.21% of GDP), while Malta spent just 0.03% (Figure 1). In Czechia, Slovakia, and Poland, total fossil fuel subsidies were equivalent to 0.62%, 0.45%, and 0.31% of GDP, respectively, although one must point to the scale of coal subsidies in Poland and Slovakia (0.2% of GDP).

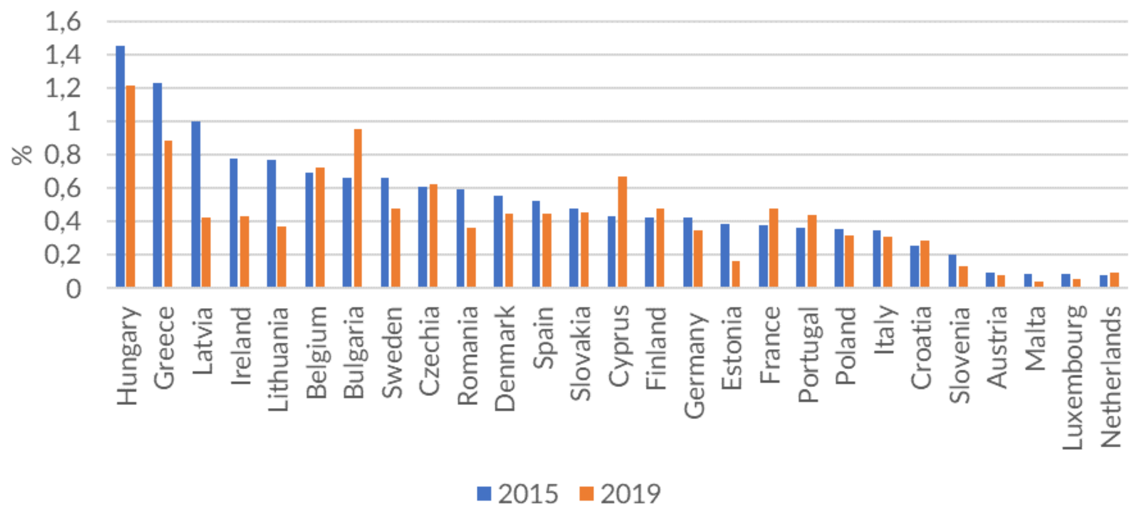


Figure 1. Fossil fuel subsidies in the EU Member States as a per cent of GDP, 2015 and 2019

Source: own study based on European Commission (2020b); Eurostat (2022).

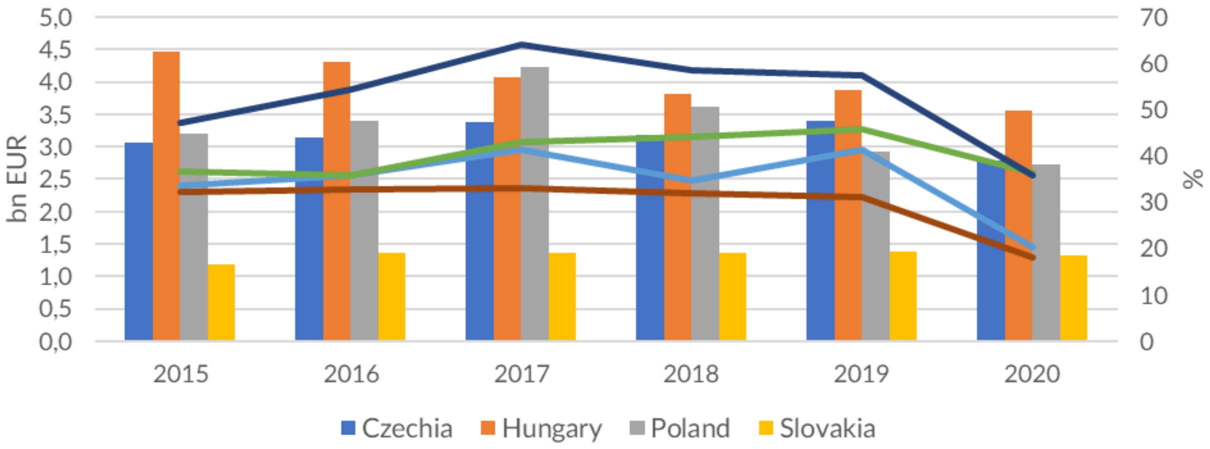
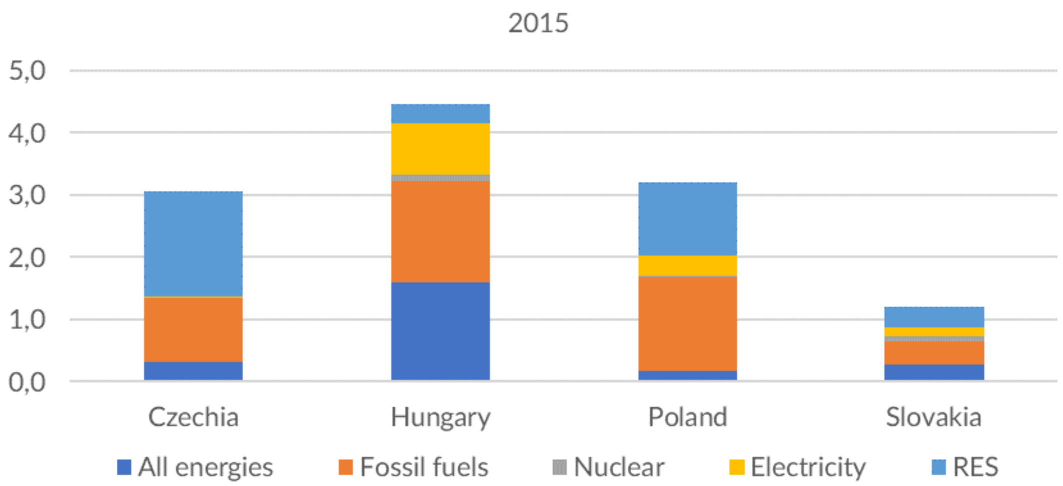


Figure 2. Energy subsidies (line, left axis) and the share of fossil fuel subsidies in total energy subsidies (columns, right axis) in V4, 2015–2020

Source: own study based on European Commission (2020b).

While focusing on V4 countries, attention should be drawn to the tendency regarding subsidy volumes and the share of fossil fuel subsidies in total energy subsidies. The data have been aggregated in Figure 2. In Hungary and Poland, subsidy volumes have been reduced by 13% and 9%, respectively, compared to 2015. The reverse is true in Czechia and Slovakia, i.e., there was an increase of 11% and 16%, respectively. While focusing on the share of subsidies for energy from conventional sources, there is a relatively constant proportion between 2015 and 2019, followed by a reduction in all economies in 2020. Nevertheless, between 2015 and 2020, Poland spent twice as much on aid to conventional energy sources than the remaining energy sources (54%), compared to Hungary (40%), Czechia (35%), and Slovakia (30%).



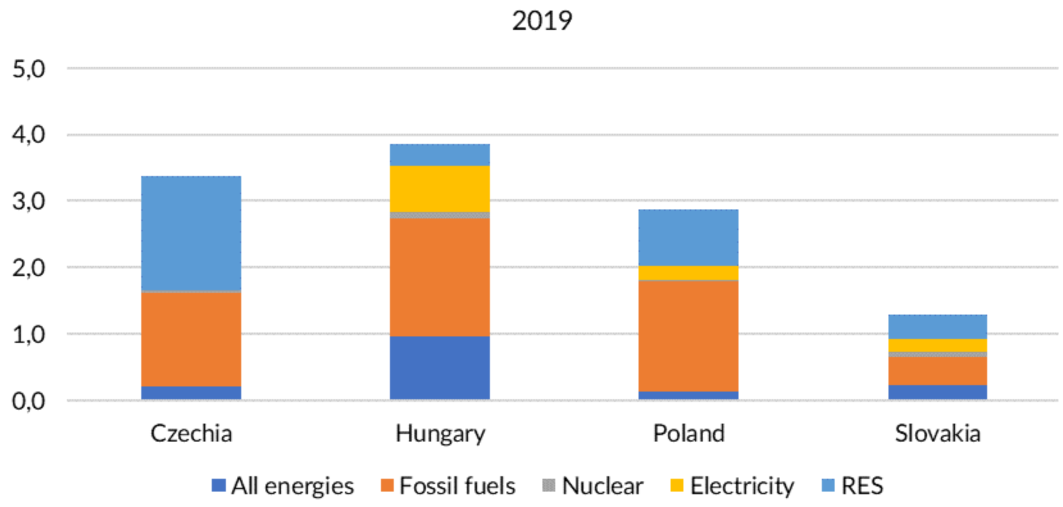
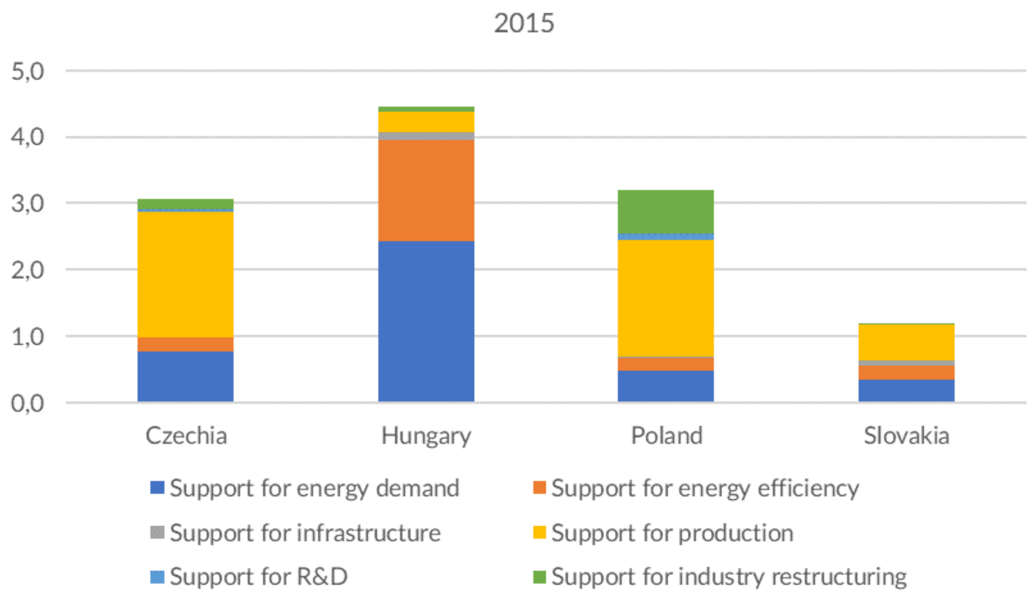


Figure 3. Energy subsidies (€2018 bn) by energy carrier in V4 countries, 2015 and 2019

Source: own study based on European Commission (2020b).

The volume of subsidies in 2019, broken down by energy media, shows that the support for renewable energy sources (Figure 3) constituted 50% in Czechia, 8.7% in Hungary, 29% in Poland, and 27% in Slovakia. Furthermore, when comparing the amount of support given in 2015, Czechia, Hungary, and Slovakia recorded growth of 2%, 10%, and 13%, respectively, while Poland recorded a decrease of 29%.

The trends are also confirmed by the types and orientation of energy subsidies. In the Czech and Slovak economies, the subsidy structure presented in Figure 3 is dominated by subsidies that support production. In Hungary, most funds were intended to support demand, while in Poland, the proportions between the support for production and consumption, as well as industry reconstruction, remain at a similar level.



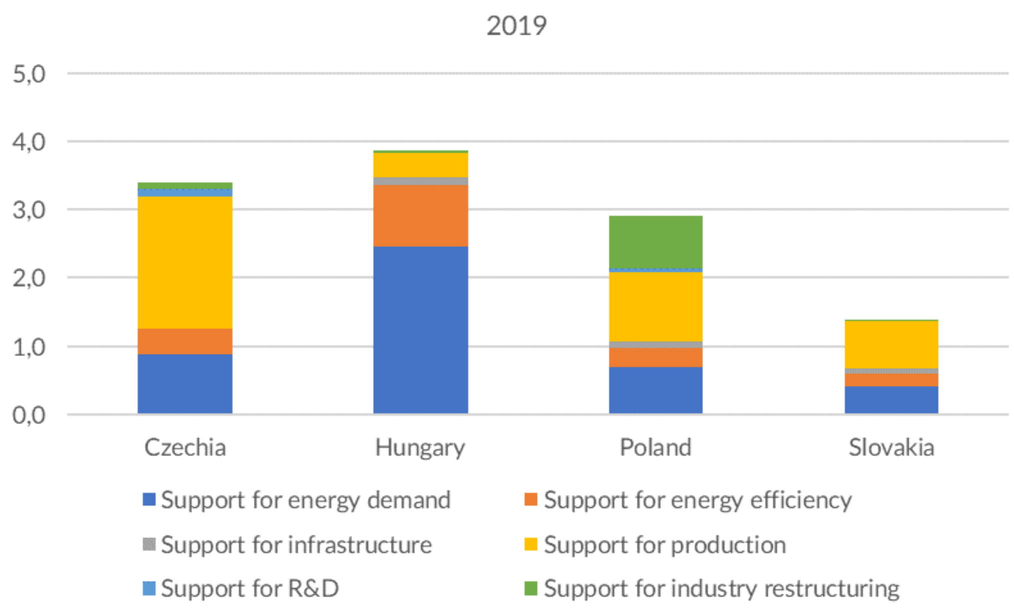


Figure 4. Energy subsidies (€2018 bn) by type in V4 countries, 2015 and 2019

Source: own study based on European Commission (2020b).

Subsidies to improve energy efficiency, however, constituted a smaller share in total expenditures: from 10% in Poland to 23% in Hungary.

Research methodology

Assuming that energy subsidies have significant implications for the pace of the EU's energy transformation by affecting the energy consumption levels and the types of fuels used, we seek the dependencies and impact of fossil fuel subsidy volumes on CO_2 emissions in the V4 countries. To assess the relationship between a dependent variable and an independent variable, a linear regression model is used.

Table 1. Fossil fuel subsidies in V4 countries, 2015–2020 (€2020 bn)

	2015	2016	2017	2018	2019	2020
Czechia	1.0282	1.1293	1.4009	1.1049	1.4093	0.5678
Hungary	1.6363	1.5440	1.7453	1.6873	1.7702	1.2973
Poland	1.5144	1.8492	2.7084	2.1233	1.6705	0.9807
Slovakia	0.3800	0.4491	0.4504	0.4387	0.4270	0.2387

Source: own study based on European Commission (2020b).

Table 2. Fossil CO_2 emissions in V4 countries, 2015–2020 (Mt CO_2)

	2015	2016	2017	2018	2019	2020
Czechia	107.728	109.155	110.015	108.840	105.107	92.082
Hungary	47.325	48.185	50.712	50.402	50.437	49.405
Poland	306.053	317.068	330.422	330.801	312.917	292.562
Slovakia	34.525	35.523	37.549	37.525	34.651	31.871

Source: own study based on Crippa et al. (2021).

In 2020, fossil fuel subsidies in the V4 countries were noticeably lower than in previous years (by more than half). The scale of emissions is also lower, although the difference is not as drastic (Table 1 and Table 2). It is thus worth considering both models that account for 2020 and excluding that year. It is interesting how subsidies from the previous year affect emissions in a given year. As a consequence, the analysis includes models with a time shift by a year (lag) and without it, namely showing how emissions in a given year are affected by subsidies from a given year. The relatively small amount of available and comparable data, i.e., six time points, makes it impossible to measure the impact of subsidies from a previous year and subsidies from a given year in one hierarchical model. Thus, four models were obtained:

- a model without a lag and including 2020,
- a model with a time lag and including 2020,
- a model without a lag and excluding 2020,
- a model with a time lag and excluding 2020.

Each is a linear model that defines the relationship between the dependent variable and the explanatory variable. The model without a lag and including 2020 is expressed as:

$$E_t = \alpha + \beta S_t + \varepsilon, \qquad (1)$$

where: *Et* is the emissions volume, *St* – the volume of subsidies in year t, α is the intercept, and β is the model parameter. We also assume that random error is characterised by normal distribution: $\varepsilon \sim N\left(0, \sigma^2\right)$.

In turn, the model with a time lag and including 2020 is expressed as follows:

$$E_t = \alpha + \beta S_{t-1} + \varepsilon, \qquad (2)$$

where: *Et* is the emissions volume in year t, and *St–1* is the volume of subsidies in the previous year (*t* = 2016, 2017, …, 2020; we omit 2015 due to the absence of data from the previous year). Other definitions are identical as in the model without a lag and including Models excluding 2020 have an analogical structure, but here we accounted for *t* = 2015, 2016, …, 2019 and *t* = 2016, 2017, …, 2019, respectively. All models include the β parameter, which shows the impact of subsidies on emissions.

Results and discussion

In all four models for the Czech economy, p > 0.05 was obtained, which means that the dependence is of no statistical importance (Table 3). Additionally, three tests were performed for each model:

- the Shapiro-Wilk test to check the assumption that ε is indeed characterised by a normal distribution,
- the Durbin-Watson test to check that no autocorrelation is present, i.e., whether ε from one year depends on ε from the previous year,
- the Breusch-Pagan test for heteroscedasticity of ε, i.e., whether it is variable in time.

Table 3. Models estimation for the Czech economy

Trait	Parameter	95%CI		p*
Model without a lag and including 2020				
Energy subsidies (bn euro)	17.554	4.554	30.554	0.057
Model with a lag and including 2020				
Energy subsidies in the previous year (bn euro)	– 23.792	– 63.033	15.449	0.32
Model without a lag and excluding 2020				
Energy subsidies (bn euro)	– 2.59	– 14.293	9.114	0.694
Model with a lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	1.781	– 16.578	20.14	0.867

p – univariate linear regression; *statistically significant (p < 0.05).
Source: own study.

The assumptions of the model are met when test results are of no statistical importance, i.e., when the p-value remains above 0.05. When diagnosing the models, we must also point out the problem of breaching the assumptions in the test for the model with the time lag and including 2020 and the model without the lag and excluding 2020 (Table 4).

Table 4. Model diagnostics for the Czech economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.135	p = 0.186	p = 0.912
With lag, with 2020	p = 0.999	p = 0.037*	p = 0.026*
Without lag, without 2020	p = 0.963	p = 0.075	p = 0.032*
With lag, without 2020	p = 0.356	p = 0.103	p = 0.397

p – univariate linear regression; *statistically significant ($p < 0.05$).
Source: own study.

The first and the last models allow us to state that in the Czech economy, CO_2 emissions do not depend on subsidies either from the present or the previous year.

Table 5. Models estimation for the Hungarian economy

Trait	Parameter	95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	2.912	– 4.316	10.139	0.474
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	– 1.361	– 14.314	11.591	0.85
Model without lag and excluding 2020				
Energy subsidies (bn euro)	13.498	1.604	25.393	0.113
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	0.221	– 18.839	19.281	0.984

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

With the Hungarian economy, as in the previous example, all four models yielded $p > 0.05$, confirming no statistical importance (Table 5).

At this phase of the analysis, there is a problem with the model without lag and including 2020, as well as the test regarding the model with lag and excluding 2020 (Table 6). All models, however, lead to the same conclusion. However, based on the model with lag and including 2020, as well as the model without lag and excluding 2020, we can state that the emission levels do not depend on subsidies from either the present or the previous year.

Table 6. Model diagnostics for the Hungarian economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.036*	p = 0.022*	p = 0.966
With lag, with 2020	p = 0.053	p = 0.088	p = 0.453
Without lag, without 2020	p = 0.303	p = 0.14	p = 0.458
With lag, without 2020	p = 0.037*	p = 0.215	p = 0.584

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

Table 7. Models estimation for the Polish economy

Trait		95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	23.763	15.57	31.957	0.005
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	17.303	– 15.068	49.673	0.372
Model without lag and excluding 2020				
Energy subsidies (bn euro)	20.659	8.52	32.798	0.045
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	7.941	– 14.694	30.576	0.563

p – univariate linear regression, * statistically significant ($p < 0.05$).
Source: own study.

In the model without lag and including 2020, the p-value amounts to 0.005; therefore, the statistical dependence of variables has been confirmed. The regression parameter (β) totals 23.763; therefore, each further billion euros increases emission by an average of 23.763 Mt. In turn, in the model with the lag and including 2020, the p-value points to dependence of no statistical significance, i.e., subsidies from the previous year do not affect CO_2 emissions.

According to the calculations in Table 7, the model without the lag and excluding 2020 points to a dependence of statistical significance ($p < 0.05$). The regression parameter (β) totals 20.659; therefore, each further billion euros increases emissions by an average of 20.659 Mt. This is similar to the inclusion of 2020, although the impact of subsidies is slightly lower and much less significant here. As in the model with the lag and including 2020, and in the model with the lag and excluding 2020, the calculated dependence is of no statistical significance ($p > 0.05$). Thus, here subsidies from the previous year also do not affect emissions in the current year.

While moving to model diagnostics (Table 8), we must point out the p-value for the model with lag and including 2020 ($p = 0.049$, i.e., exactly the threshold value), which means that it must be treated with caution.

Table 8. Model diagnostics for the Polish economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.65	p = 0.75	p = 0.158
With lag, with 2020	p = 0.963	p = 0.049*	p = 0.204
Without lag, without 2020	p = 0.192	p = 0.665	p = 0.49
With lag, without 2020	p = 0.965	p = 0.217	p = 0.905

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

Finally, therefore, according to the model without lag and excluding 2020, as well as the model with lag and excluding 2020, subsidies from a given year increase emissions in that year, while subsidies from the previous year do not have an impact. The data from 2020 break the model assumptions, which is why they have not been included here. This means the situation is worth observing.

Table 9. Models estimation for the Slovak economy

Trait	Parameter	95%CI		p*
Model without lag and including 2020				
Energy subsidies (bn euro)	22.687	10.053	35.321	0.024
Model with lag and including 2020				
Energy subsidies in the previous year (bn euro)	24.533	– 63.068	112.135	0.621
Model without lag and excluding 2020				
Energy subsidies (bn euro)	33.792	– 10.357	77.941	0.231
Model with lag and excluding 2020				
Energy subsidies in the previous year (bn euro)	21.871	– 30.434	74.176	0.499

p – univariate linear regression, * statistically significant ($p < 0.05$).
Source: own study.

Calculations for the model without lag and including 2020 (Table 9) allow us to state that the dependence is statistically significant ($p < 0.05$). The regression parameter (β) totals 22.687; therefore, each further billion euros increases emissions by an average of 22.687 Mt. In turn, in the other three models in Table 9, the dependence is of no statistical significance ($p > 0.05$). Furthermore, excluding 2020 in the model without the lag completely changed the conclusion from the analysis of the model that includes 2020.

Table 10. Model diagnostics for the Slovak economy

Test	Shapiro-Wilk test	Durbin-Watson test	Breusch-Pagan test
H0	Normality of errors	No autocorrelation	Homoscedasticity
Without lag, with 2020	p = 0.644	p = 0.595	p = 0.075
With lag, with 2020	p = 0.097	p = 0.013*	p = 0.972
Without lag, without 2020	p = 0.326	p = 0.546	p = 0.123
With lag, without 2020	p = 0.053	p = 0.224	p = 0.498

p – univariate linear regression; * statistically significant ($p < 0.05$).
Source: own study.

When diagnosing the models, there is again an issue regarding the model with the lag and 2020, as was the case with Poland (Table 10). Finally, according to the models that exclude 2020, emissions are independent of subsidies from the current and previous year. We must point out that the data from 2020 break the model assumptions, which is why they have not been accounted for. The situation is thus worth observing, particularly since including 2020 significantly changes the result of the analysis.

Concluding remarks

The literature provides evidence that fossil fuel subsidies are not only a burden for public budgets, exhausting the limited fiscal resources, but that they also distort the costs and prices that affect decisions made by many manufacturers, investors, and consumers, thus instilling the use of older technologies and more energy-intensive production methodologies. Fossil fuel subsidies thus undermine the efforts to mitigate climate change and hinder effective energy transformation.

The research into the scale and structure of subsidies for conventional energy sources reveals that, in all four countries, they remained at a constant level between 2015 and 2019. However, the data for 2020 point to significant limitations of both total energy subsidy volume and the share of fossil fuel subsidies (except for Slovakia).

While answering the research question regarding the dependence and impact of fossil fuel subsidies on CO_2 emissions, conclusions were drawn regarding the linear model coefficients. However, the data gathered do not constitute strong proof for the accuracy of the hypothesis. Nor do they confirm the impact of subsidy volume (from either the current or previous year) on CO_2 emission levels. The conclusion, although significant from the application point of view, must be treated with caution. The problem is important and requires further statistical observation as this research relied on a relatively short range of data due to the availability of comparable statistical data.

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Subsydia energetyczne i ich konsekwencje dla emisji CO_2 w krajach Grupy Wyszehradzkiej

Celem artykułu jest przedstawienie przeglądu literatury na temat subsydiów energetycznych, skali i struktury dopłat do produkcji energii w krajach Grupy Wyszehradzkiej. Zaprezentowano też najważniejsze wyniki próby zbadania zależności i wpływu subsydiów do paliw kopalnych na emisje CO_2 na podstawie modelu regresji liniowej. Ze względu na dostępność porównywalnych danych statystycznych badanie ograniczono do okresu 2015–2020. Przeprowadzona analiza nie stanowi jednak mocnego dowodu na jednoznaczne potwierdzenie negatywnego wpływu wysokości dotacji (z roku bieżącego lub poprzedniego) na poziom emisji CO_2.

Słowa kluczowe: CO_2, dotacje, kraje V4, paliwa kopalne