Master Thesis U.S.E.

Utrecht University

School of Economics

Influence of economic and political factors on low-carbon electricity production in the context of EU energy policy[1]

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Abstract:

Various studies suggest that economic and political factors may influence energy transition across countries. This paper investigates relationships between those factors and low-carbon electricity production, which implicitly represents an energy policy of a government. A certain innovation in this study is the use of an additional model incorporating natural gas among other low-carbon energy sources. Despite the present literature is not covering it, this is in line with the current policy practice, and therefore it is worth to be examined. An analysis of the recent studies imply that factors like national wealth, economic inequality and the state of democracy in particular countries may affect the energy policy. This paper focuses on exploring these potential relationships across the member states of the European Union and then discussing it within the specific context of EU regulatory framework related to the energy policy. The research question this paper is aiming to answer is as follows: Do national wealth, income inequality and state of democracy have an influence on the share of low-carbon energy sources in electricity production across EU countries faced with EU climate policy? The study uses panel data regression analysis as a main component of the methodology. Conclusions derived from the research suggest that from the factors discussed, only national wealth is the one that affect the energy transition process in the EU countries. This finding may be useful in the process of designing the energy policies. Better understanding of the matter regarding the differences between the EU countries in the energy transition can help to mitigate uneven peace of this process.

Key words: energy transition, energy policy, economic inequality, national wealth, democracy, European Union

JEL-codes: C23, Q43, Q48

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1. Introduction

In recent years, the global community has become increasingly aware of an urgent need to address climate change and transition to low-carbon energy sources. Policymakers representing various countries take joint efforts to reduce greenhouse gas emissions resulting from human economic activity, as well as to mitigate negative effects of an arising environmental crisis.

The authorities of the European Union (EU) aim to be the world leader in energy transition, formulating ambitious objectives for the policies within this alliance (European Commission, 2018). In current EU's policy practice, further development of a sustainable energy system is among the top priorities. European Commission's Climate Target Plan aims to cut greenhouse gas emissions by at least 55% by 2030, and further to become climate neutral by 2050 (European Commission, n.d.). The European Union is one of the 194 parties that have signed the Paris Agreement. The supreme point of this declaration is "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations, 2015, p. 3).

Declarations mentioned above are followed by actual actions. This can be observed, for example, in the distribution of the EU funds. From the funds of the NextGenerationEU, the largest stimulus package in the EU history, established to help the member states recover from the crisis of the COVID-19 pandemic, 30% of the budget is allocated to the fight against the climate change (European Commission, n.d.) Such a high share of the budget has never before been dedicated to this particular purpose. Climate objectives are also supported by relevant regulatory policies. EU's legislation for promoting low-carbon electricity production reaches back to the early 21st century. In 2001 the first Renewable Energy Directive came into force, setting targets for the share of renewable energy in each member state's electricity production (Official Journal of the European Communities). In 2005 the Emissions Trading System (ETS) was established, in order to limit emissions from around 10,000 installations in the energy sector and manufacturing industry, as well as aircraft operators (European Commission, n.d.). ETS covering around 40% EU's greenhouse gas emissions is additionally supported since 2018 by Effort Sharing Regulation (ESR), which covers almost 60% emissions, not covered by ETS, represented mainly by the agriculture, buildings, road transport and waste sectors (CAN Europe, 2022).

This paper examines whether economic and political factors such as an affluence of a society, income inequality and state of democracy in particular member states of the European Union have an impact on energy transition. Mentioned factors are often analysed in studies related to the approach to climate change mitigation in specific countries. However, the European Union member states shape their policies basing on EU regulations and directives, which binds all associated countries. This research is limited to these countries only.

In a democratic system, government's decisions on energy transition are made based on the expectations of an electorate. This implies that factors characterising society, such as wealth or inequality, may affect voters' attitudes, the state of democracy may affect the relation between government policies and voters' expectations. Moreover, climate change mitigation and democratisation may be interdependent because in more democratic countries, greater value is placed on human life and life quality, and therefore there is a greater drive to care for a common good that is the environment and the planet (Burnell, 2014).

There can be find evidence that wealth of a society is somehow correlated with treating the climate change as a serious issue by citizens (Lo & Chow, 2015) or being concerned with it (Sandvik, 2008). Unfortunately, when analysing the findings of the literature jointly, one reaches ambiguous conclusions as to whether this correlation is positive or negative. For this reason, it is worth investigating the subject further in order to achieve clean results. Moreover, according to the theory of political economy it can be proven that the poorer the median voter is compared to a hypothetical agent with an average income in a specific country, the less they will care about the environment (Kempf & Rossignol, 2005). In other words, the more unequal the distribution of wealth, the lower the importance attributed to caring for the environment, and the lower the inequality of wealth distribution, the higher the environmental concern should be in a given society. In consequence, these economic factors may influence energy policies undertaken by a government. Therefore, it is worth analysing if the wealth of the country measured as GDP per capita, as well as the income inequality measured by the Gini index, influence the share of low-carbon energy sources in electricity production of a specific country.

Furthermore, there was a research made that showed a positive correlation between the state of a democracy and the share of low-carbon energy in electricity production (Clulow & Reiner, 2022). That study indicated, that generally democratisation supports the energy transition towards a system operating with lower emissions. In the same research it was proven that for some types of low-carbon sources of energy, high level of GDP per capita strengthens the effect that democratisation has on the use of low-carbon energy sources for electricity generation in the energy mix. For this reason, the democracy is something that this paper will also include among explanatory variables.

The Clulow and Reiner's (2022) research includes only nuclear energy and renewable energy as the low-carbon sources of electricity generation. However, EU authorities, as well as some of the member states are considering natural gas as source of the low-carbon energy (Abnett, 2022). The reason behind such approach is the fact, that producing the same amount of energy while using natural gas is associated with emitting over two times less of carbon dioxide (CO_2) to the atmosphere compared to coal (Schlömer et al., 2014, p.7).

The research question this paper is aiming to answer is as follows:

Do national wealth, income inequality and the state of democracy have an influence on the share of low-carbon energy sources in electricity production across EU countries faced with EU climate policy?

Basing only on the existing literature, this question cannot be answered. There is no research directly focusing on the first two factors and their influence on the share of low-carbon energy sources in electricity production. In addition, the available literature captures the problem from a global perspective without taking into account the specific political framework of the European Union. Moreover, in the literature natural gas is not considered as a low-carbon source of energy, despite the fact that investments in the natural gas power plants in this context are present in the European policy practice for more than a decade (The Guardian, 2012).

What is worth emphasising, this paper is taking into account electricity production, and not the whole energy consumption (e.g. related to transport or heating). The reason behind this is the fact that electricity is mostly dependent on energy policies undertaken by a government. For example, ensuring the electricity supply is highlighted as one of the Dutch government objectives (Government of the Netherlands, n.d.). An electricity production system is mostly a government's responsibility, while other aspects of the energy system are often dependent on individuals' behaviour. In other words, the system of electricity production shows a rather top-down process of transition, coming from the initiative of state authorities. Considering only electricity production, allows for the best comparison of energy systems between different countries. For this reason, exactly such a measure was used in the study by Clulow and Reiner (2022).

The motivation for this study was its social and political relevance. Conducting the research could have yielded two variants of results and therefore two different policy recommendations.

1) Some or all of the factors analysed may have an impact on the energy transition.

   In this case, the European Union should adjust its climate policy with greater emphasis on differentiation between the countries, taking into account their specific characteristics.

2) The analysed factors do not affect the energy transition.

   The results in such a scenario would show that the European Union's climate policy, as it currently stands, is designed correctly and does not need to be differentiated between the member states on the basis of the factors described.

Moreover, this research makes it possible to verify some of the assumptions of the other studies, restricting it to the EU member states, which operates in a very specific regulatory framework. In addition, this study examines whether the inclusion of natural gas, which is in line with the actual policy practice of low-carbon electricity production, influences the conclusions obtained and somehow changes the picture of the energy transition.

2. Literature Review

Literature which examines a relationship between an energy policy or electricity production structure and factors such as national wealth, economic inequality or the state of democracy is very limited. Nevertheless, a potential connection can be derived from the papers referring indirectly to these issues. The findings from the literature are mixed, leaving space for further research. The classification can be used in which the literature is divided into two sections. The first section contains the studies suggesting that the society's wealth may reduce its willingness to fight the climate change. The second section, in contrast, contains the studies suggesting that the wealth of a society can positively influence the willingness to address the climate change. Moreover, in the second section two additional types of papers are discussed. One is suggesting negative correlation between the economic inequality in a society and the society's concern regarding environmental protection, the second paper is suggesting positive correlation between the state of democracy in a particular country and the stage of energy transition.

2.1. Society's affluence and concern with the climate change

It can be assumed that in democracy government makes an energy policy notably based on the voters expectations. According to Sandvik's (2008) cross-national study, concern relating to the climate change is negatively correlated with the wealth of the nation measured as GDP per capita. This results was then confirmed by a more recent study (Nauges et al., 2021). Findings of Kim and Wolinsky-Nahmias (2014) are also in line with the findings of Sandvik (2008). This research however is using Gross National Income per capita instead of Gross Domestic Product per capita to measure wealth of a society, proving empirically that GNI per capita is negatively correlated with the climate change concern.

In this context, it is also worth mentioning the paper by Lo and Chow (2015) who examined how people perceive the risks of the climate change according to their affluence. Their study shows that citizens of the countries that have greater national wealth expressed as GDP per capita are more likely to downplay the threat of the climate change, even if they consider it to be the most important environmental problem to be solved. The reason behind this may be that in more affluent countries people generally feel more secure, and despite being aware of the need to handle the climate change, they tend to believe they will not be affected directly by it.

Findings mentioned in previous paragraph suggest that the wealth expressed as GDP per capita should not stimulate the voters to support government which prioritise fight against the climate change expressed, inter alia, as the energy transition. However, there are also other findings described in second section of this literature review that suggest the exact opposite.

2.2. The relationship of the climate change mitigation with wealth, inequality and democracy

This section refers once again to the paper authored by Kim and Wolinsky-Nahmias (2014). It is important to mention that despite not being very concerned about the effects of the climate change, individuals may still take steps to address its mitigation. According to this study, people living in countries with higher GDP per capita are more likely to pay high financial cost related to taking steps against the climate change but at the same time they are less likely to personally act against it (ibid., p. 15-16). It may suggest that in wealthier countries people do not want to change their convenient life-style, but they want to financially contribute to the action undertaken for example by a government. Although the relationship between GDP per capita and people's attitudes towards the climate change is ambiguous, it is reasonable to assume that this is a factor that can influence an energy policy. The direction of this impact needs to be empirically tested.

Similar thing applies to paper authored by Lo and Chow (2015). As mentioned in the first section of literature review, there is a need to treat separately risk perception and importance perception. While GDP per capita in a specific country is correlated negatively with considering the climate change to be dangerous for the people that were surveyed, wealth is positively correlated with calling climate change the most important environmental problem (ibid., p. 6-9). It is most noticeable with Norway, which has the highest GDP per capita of the countries used in this study. Norwegian respondents were at the same time second in terms of identifying the climate change as a serious environmental problem and penultimate in terms of being afraid of the consequences arising from it.

In addition to wealth, two other factors that have been identified as potentially influencing the energy policy in a particular country should also be considered: inequality and democratisation. In a theoretical paper, Kempf and Rossignol (2005) study the issue of the long-term impact of income distribution on the environment. They present a trade-off between the economic growth and the environmental protection. In the model democratic state, the greater the difference between the median voter income and the average income in the country’s economy, the higher the priority given to the economic growth over the environmental protection. This is simply explained by the fact that people relatively richer than the rest of society are proportionally more concerned with the quality of the environment, while the poor people relatively care more about the economic growth (ibid.). This relationship is partially confirmed by empirical research. Evidence can be found that in countries with higher economic growth, higher levels of supportiveness for the environmental protection is present (Gelissen, 2007). Presumably, the reason for this is that with rapid economic growth, people are more willing to devote a part of it to the environmental protection, as the trade-off dilemma is weaker. Another paper in favour of this concept indicate that an increase in wealth is associated with higher demand for good quality environment (Franzen, 2003, p. 306). For the theoretical framework of this paper, these environmental considerations are applied to the field of the climate change. Using the paper by Kempf and Rossignol (2005) as a basis, it is worth examining the relationship between inequality and the energy policy across EU countries. It is worth mentioning that the impact of inequality should be considered in the context of individual countries rather than the

European Union as a whole, as people's relative perceptions of their own wealth are based on their comparisons with their close community, e.g. the country they are living in (Sánchez-Rodríguez et al., 2019).

Clulow and Reiner (2022) proved in an empirical research based on a panel data regression that democracy promotes energy transition. They found that in more democratic countries, the share of low-carbon sources of energy used for electricity production is higher. What is also worth mentioning, the low-carbon energy sources generally increase their share in the electricity production as the state of democracy improves over time. Moreover, according to the paper, the wealth measured as GDP per capita increases the positive effect of democratisation on low-carbon energy usage. Using an observation from another origin, article by Povitkina (2018) provides a complex view on political institutions and energy transition. It acknowledges that in more democratic countries in fact the energy transition is further developed, but only if there are no corruption problem at same time.

Despite the relationship between GDP per capita and people's attitudes towards the climate change being ambiguous, one can assume that this is a factor that can impact an energy policy. There is some evidence suggesting that there may be indirect negative correlation between GDP per capita and the energy policy supporting use of the low-carbon energy sources, but on the other hand there is some evidence suggesting positive correlation. Therefore, there is space for further research. Depending on the specific characteristics of the countries studied, the effect may occur, but there is no guarantee as to its direction.

When it comes to inequality and the state of democracy, literature is more limited, but simultaneously gives more explicit point of view. Basing on the literature two notion can be formulated. Firstly, in democratic countries the higher inequality the less the government would take care of environmental issues, including the climate change. Secondly, in countries with better state of democracy, use of the low-carbon energy sources in the electricity production should be higher.

2.3. Research gap identification

The existing literature is not providing an answer for the question if there is a connection between the national wealth expressed as GDP per capita, and the share of low-carbon sources in electricity production. Neither does it provide empirical evidence of the relationship between income inequality in the country and its energy policy. The present studies explore people's attitudes to the environment and the climate change according to their affluence, but no one has investigated whether this has an impact on an energy policy expressed as the share of low-carbon energy sources in electricity production. There is a major research gap that can be filled with this paper. The closest to meeting it so far was the paper by Clulow and Reiner (2022). Nevertheless, its main focus was on issues of democratisation and electricity production. That study, though, is the inspiration behind the inclusion of the state of democracy as another explanatory variable in this paper.

It is also worth emphasising that in all the studies mentioned in the literature review above, the global perspective is analysed, with no particular focus on the European Union itself. Taking into account only the EU member states may give different results from previous studies, due to the specificity of the links between them in terms of policy-making.

3. Theoretical Framework

The conclusion derived from existing literature may be as follows. The wealth of a society expressed by GDP per capita may influence people's attitude regarding the climate change, both negatively and positively. Because of the fact that authorities often shapes policies, including those related to the climate change mitigation, based on the citizens expectations, it is worth to check relation between GDP per capita and an energy system in particular countries. The literature also suggests that counties with higher economic inequality are less likely to invest in energy transition. Lastly, there is empirical evidence that state of democracy is positively correlated with the energy transition, expressed as the share of low-carbon energy sources in electricity production. These allows to create the following hypothesis:

National wealth, economic inequality and the state of democracy influence the share of low-carbon electricity production in the EU member states.

The choice of the share of low-carbon energy sources in electricity production in particular country as the dependent variable is motivated by the fact that this was the variable used in the study by Clulow and Reiner (2022), which is closest to the issues discussed in this paper. Moreover, unlike the energy system as a whole, electricity production is most dependent on decisions taken centrally, by government institutions, and therefore more dependent on state policies than on decision made by individuals. Similarly to Clulow and Reiner (2022), it was recognised that the production of electricity would be the most suitable for such cross-country comparisons, in a paper covering the topic of economic policy.

The aim of this paper is therefore to investigate whether the hypothesis is true and eventually measure the specific effects related to it. Subsequently, findings of the empirical research will be analysed qualitatively in the context of the EU energy policy framework. Depending on whether the variables included in the study have an impact on low-carbon electricity production or not, this could lead to completely different recommendations for the European climate policy.

When it comes to the share of low-carbon energy sources in electricity production Clulow and Reiner (2022) include only renewable and nuclear energy. Even though natural gas is not free of greenhouse gases emissions when used for electricity production, its usage in power plants generates over 50% less grams of CO2 per kilowatt-hour of electricity produced compared to coal (Schlömer et al., 2014, p.7). For this reason, among EU authorities there is an opinion that natural gas may serve as a useful fuel in energy transition process. In 2022 EU lawmakers voted in favour of labelling investments in natural gas and nuclear power plants as "sustainable" (Abnett, 2022). Nevertheless, among some EU authorities natural gas has been seen as the low-carbon source of energy since over a decade (The Guardian, 2012). Moreover, the largest economy of the European Union - Germany based its energy transition process significantly on the natural gas power plants investments. Motives behind this policy were that natural gas guarantees the stability of electricity production system, while German officials decided to reduce the share of nuclear energy in energy mix (Malko, 2014). Political context suggest that natural gas should be included somehow in the research exploring the energy transition as the low-carbon source of energy, which cannot be noticed in the present literature related to the topic. This paper takes natural gas into consideration. Two different variants of the model will be used. The first one does not include the natural gas within the share of low-carbon energy source used in a specific country for electricity production. The second does the opposite and includes natural gas among the low-carbon sources of energy used for electricity production. This step allows for making even further contribution to the existing literature than just including the national wealth and the income inequality as the independent variables.

4. Data and Methodology

The source of data for the first two explanatory variables is the same. Either the national wealth represented by GDP per capita and the income inequality within a country represented by the Gini index are retrieved from the Eurostat database. At this point, it is worth mentioning that the higher the Gini coefficient, the greater income distribution inequality. Describing the used data precisely, this paper uses the real GDP per capita at constant prices from 2010 to avoid the impact of inflation and the Gini coefficient relates to disposable income before social transfers, with pensions excluded from social transfers (Eurostat, 2023). The data source for the explained variable is Eurostat as well. The fact that these variables are drawn from the same database can work in favour of obtaining reliable results. Due to the study by Clulow and Reiner (2022), democracy index is used as the third independent variable. In contrast to that research, the indicator considered is the EIU Democracy Index (Economist Intelligence Unit, 2013-2021), not the V-Dem polyarchy index. The EIU Democracy Index attempts to measure the state of democracy, evaluating it on a scale from 0 to 10 (with decimal points) basing on political factors relating to particular countries.

As it was mentioned in the previous section, two models are being considered, one that recognises natural gas as a low-carbon energy source and one that does not. The mentioned share index is obtained by dividing the sum of gigawatt-hours of electricity produced using the low-carbon energy sources by the total gigawatt-hours of electricity produced. In both cases share of the low-carbon energy sources in electricity production refers to the period one year later than the explanatory variables. This is to check whether national wealth, income inequality and the state of democracy in a given year, have an impact on the share of low-carbon energy sources in electricity production in the following year, which implicitly represents a government's energy policy. As it must be assumed that it takes time for policies to come into force, one year lag is used in the study. A version of the model without time lag is additionally included in the Appendix 1[2].

This paper's two-variant model apply to the years 2013-2021 and the 27 countries of the European Union member states, thus it is based on panel data. An empirical strategy for selecting model specification can be undertaken using the Hausman test to determine whether the regression analysis should be carried out using a fixed effects or random effects estimator (Wooldridge, 2013, p. 496).

[2] In general, a model specification without a time lag, gives similar results to those where there the time lag is present. However, the use of the time lagged model has a more solid logical basis, as it takes time to implement energy policies based on initial conditions.

4.1. Independent variables

The independent variables used in this research are as follows:

- the real GDP per capita at constant prices from 2010 expressed by "gdp"
- the Gini index regarding disposable income before social transfers, with pensions excluded from social transfers expressed by "gini"
- the score given in the EIU Democracy Index ranking expressed by "edi"

The basic characteristics of the set of independent variables are summarised in the table below:

Variable	Obs	Mean	Std. Dev.	Min	Max
gdp	243	26227.119	17009.787	5390	84750
gini	243	35.123	3.676	24.3	46.5
edi	243	7.882	.825	6.38	9.73

Table 1. Independent variables summary statistics.

For further context, distribution density functions are also included:

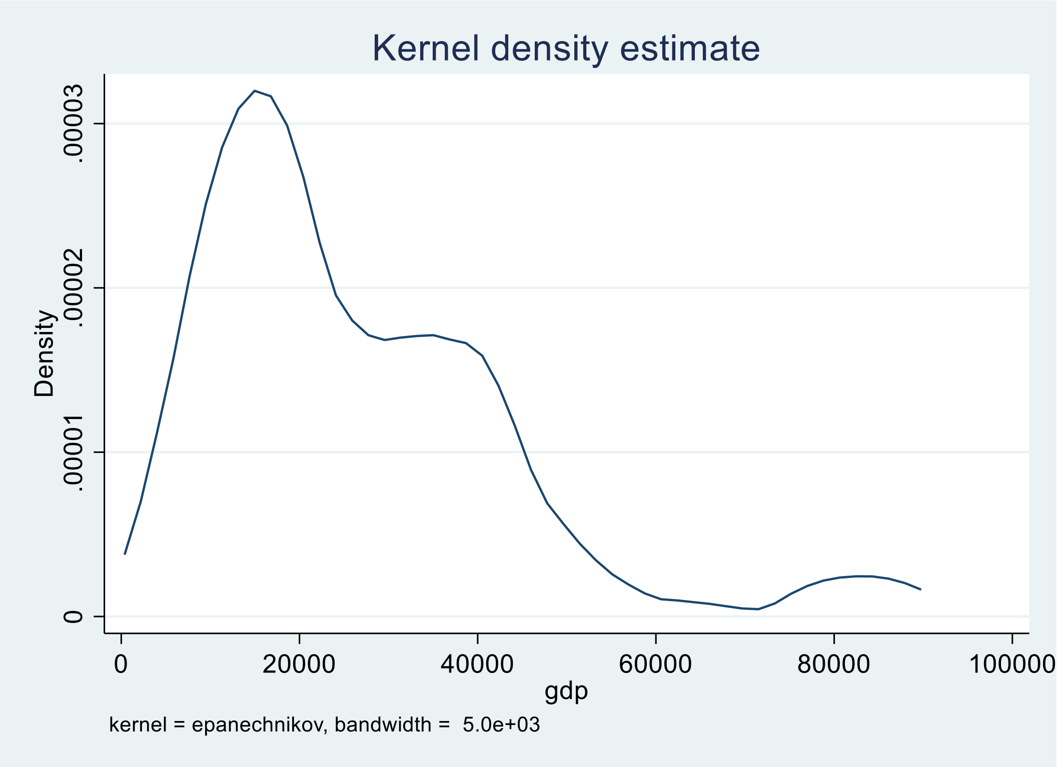

Figure 1. Density function of variable gdp (GDP per capita at constant 2010 prices).

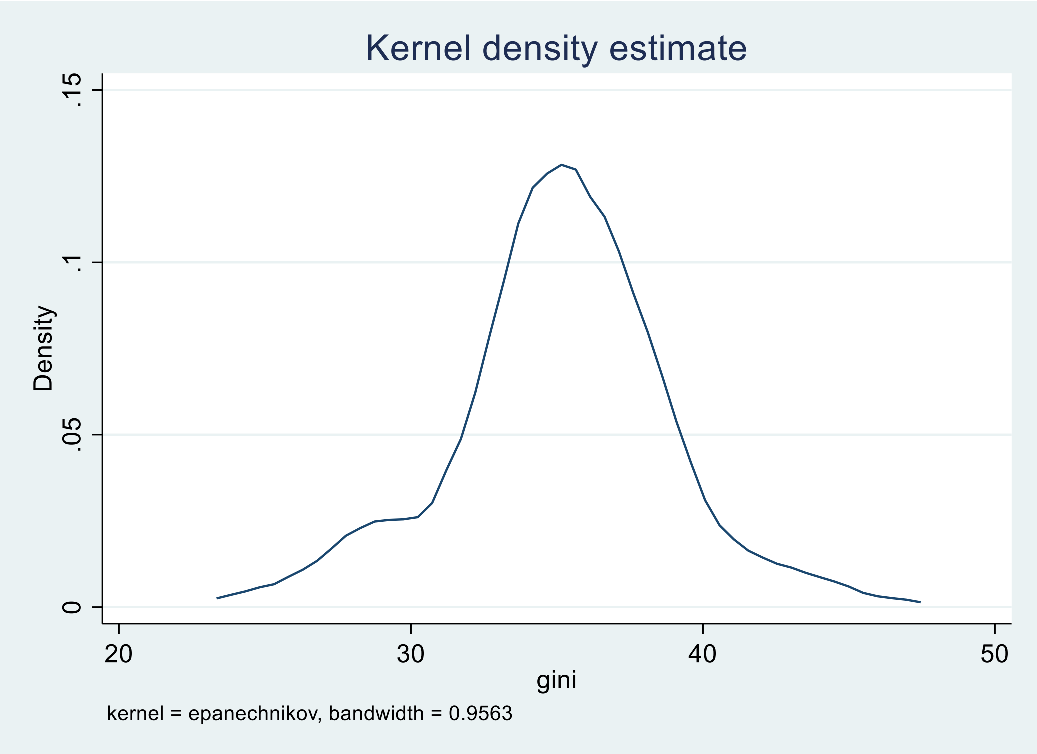

Figure 2. Density function of variable gini (Gini index).

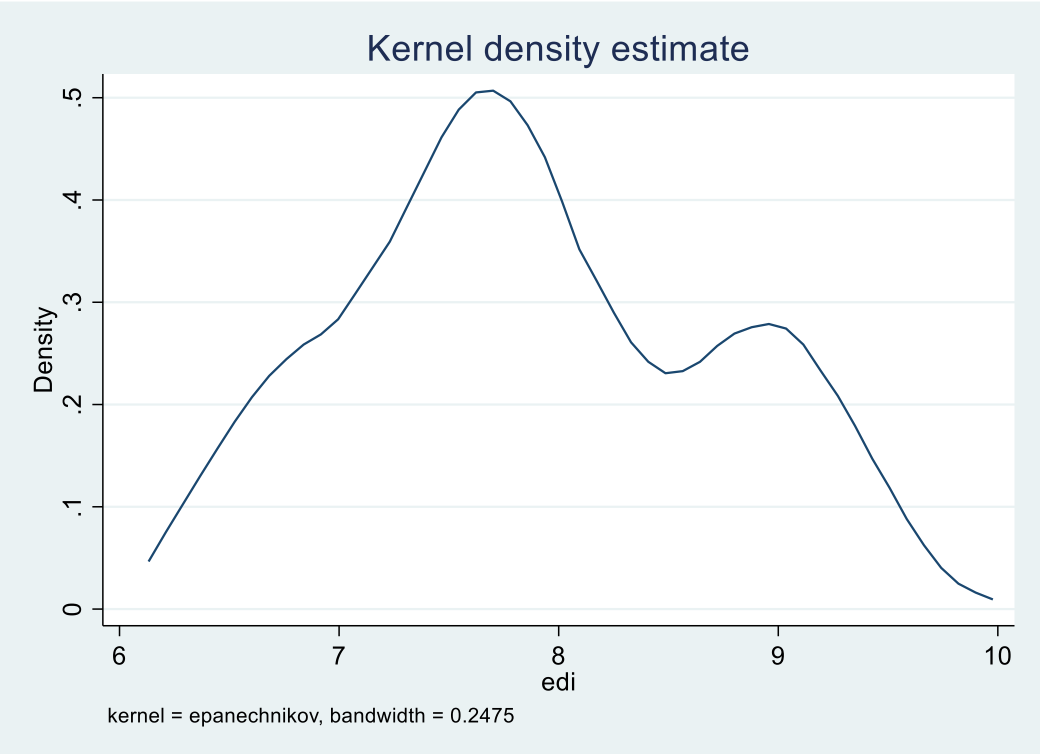

Figure 3. Density function of variable edi (EUI Democracy Index).

4.2. Dependent variables

The dependent variables used in this research are as follows:

- the share of low-carbon energy source of electricity production, where natural gas is not considered as low-carbon (use of nuclear, renewables and biofuels, relatively to total production measured by gigawatt-hour) expressed by "lcep"
- the share of low-carbon energy source of electricity production, where natural gas is considered to be low-carbon (use of renewables and biofuels, nuclear and natural gas relatively to total production measured by gigawatt-hour) expressed by "glcep"

The basic characteristics of the set of dependent variables are summarised in the table below:

Variable	Obs	Mean	Std. Dev.	Min	Max
lcep	243	.487	.224	.02	.94
glcep	243	.73	.261	.02	1

Table 2. Dependent variables summary statistic.

Similar to the independent variables section, distribution density functions are also included:

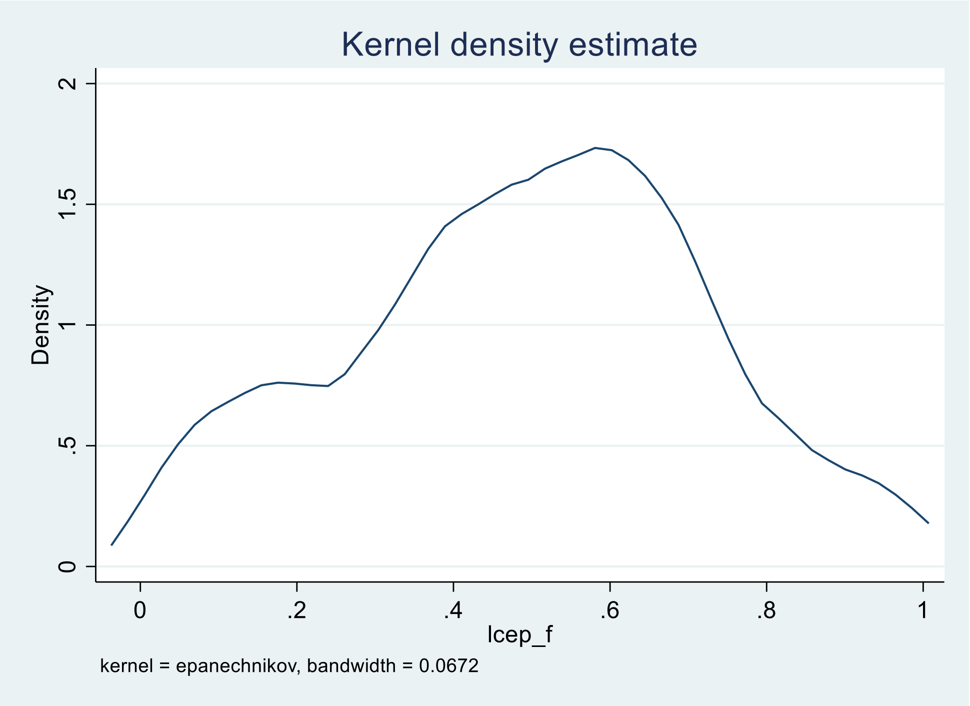

Figure 4. Density function of variable lc_ep (Share low-carbon energy sources in electricity production – gas is not included).

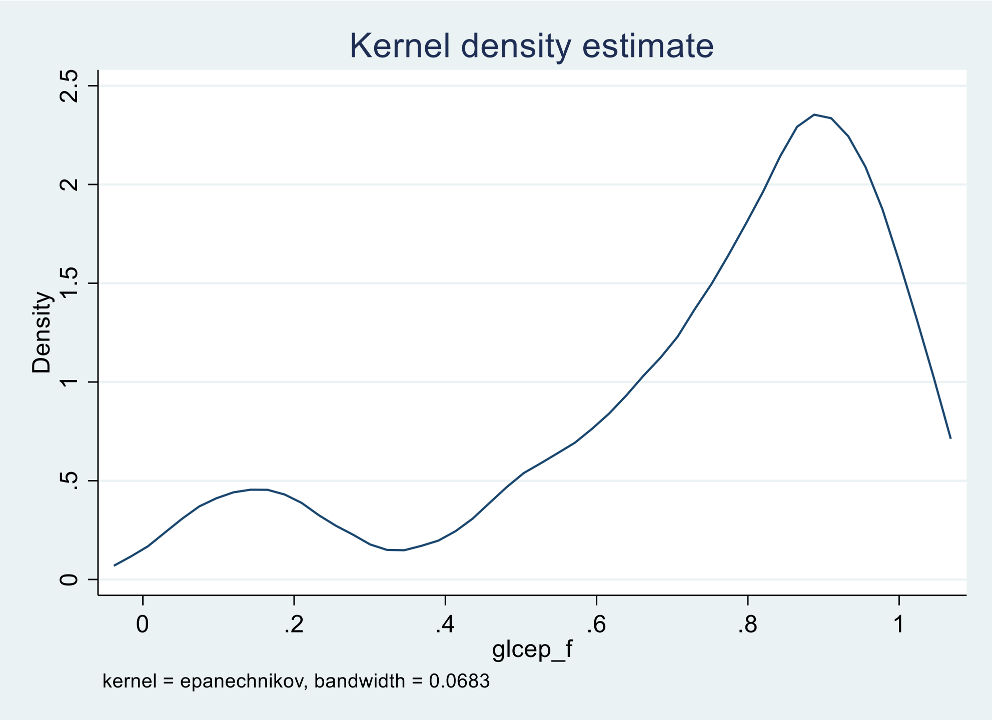

Figure 5. Density function of variable glc_ep (share low-carbon energy sources in electricity production – gas is included).

4.3. Hausman test: fixed effects vs random effects

Running the Hausman test for two specifications, depending on whether the gas is considered a low-carbon energy source, allows to check if the random effects estimator is preferred over the fixed effects estimator (Wooldridge, 2013, p. 496). The procedure for carrying out the statistical test for both models is described below.

Model 1.

RE-model: $lcep_{t+1} = \beta_0 + \beta_1 gdp + \beta_2 gini + \beta_3 edi + \alpha_i + u_{it}$

where α_i is an individual specific error term, uncorrelated with the explanatory variables.

FE-model: $lcep_{t+1} = \gamma_0 + \gamma_1 gdp + \gamma_2 gini + \gamma_3 edi + \alpha_i + \epsilon_{it}$

where α_i is an individual specific fixed effect that may be correlated with the explanatory variables.

The statistical hypotheses are as follows:

$H_0: \beta_1 = \gamma_1, \beta_2 = \gamma_2, \beta_3 = \gamma_3$

$H_1: H_0 \; is \; not \; true$

The following table shows the results of the Hausman test, with a significance level of 0.05.

Hausman specification test

	Coef.
Chi-square test value	2.613
P-value	.455

Table 3. Hausman test results for the first model.

Critical value $\chi_{0.05}(3) = 7.81$

2.613 < 7.81, in other words, test statistic is smaller than critical value and therefore H_0 is not rejected.

The evidence suggests that the individual specific effects are not correlated with the explanatory variables and that, for consistency a random effects specification is needed.

Model 2.

The test procedure for the second model, is exactly the same as in the first case, simply changing the dependent variable to one that additionally takes gas into account.

RE-model: $lcep_{t+1} = \beta_0 + \beta_1 gdp + \beta_2 gini + \beta_3 edi + \alpha_i + u_{it}$

where α_i is an individual specific error term, uncorrelated with the explanatory variables.

FE-model: $lcep_{t+1} = \gamma_0 + \gamma_1 gdp + \gamma_2 gini + \gamma_3 edi + \alpha_i + \epsilon_{it}$

where α_i is an individual specific fixed effect that may be correlated with the explanatory variables.

The statistical hypotheses are as follows:

$H_0: \beta_1 = \gamma_1, \beta_2 = \gamma_2, \beta_3 = \gamma_3$

$H_1: H_0 \; is \; not \; true$

The following table shows the results of the Hausman test, with a significance level of 0.05.

Hausman specification test

	Coef.
Chi-square test value	4.812
P-value	.186

Table 4. Hausman test results for the second model.

Critical value $\chi_{0.05}(3) = 7.81$

4.812 < 7.81, in other words, test statistic is smaller than critical value and therefore H_0 is not rejected.

The evidence suggests that the individual specific effects are not correlated with the explanatory variables and that, for consistency a random effects specification is needed.

It might seem that using a fixed effects specification would intuitively be better, as it could control for such unobservable variables as, for example, a country's access to energy resources. However, due to the better fit identified with the Hausman test, this study will be based on a random effects specification. The results for the two models with a fixed effects specification are additionally included in the Appendix 2[3].

4.4. Final version of the model used for the study

The results of the Hausman test were in favour of a random effects estimator over the fixed effects estimator. Therefore, the final version of the model used for the study is expressed in the form of the following equation:

$$y_{t+1} = \beta_0 + \beta_1 gdp + \beta_2 gini + \beta_3 edi + v_{it}$$

Where:

- y_{t+1} stands for the share of low-carbon energy sources of electricity production (model 1: renewables and biofuels, nuclear; model 2: natural gas additionally included) in the next year compared to the period to which the explanatory variables relate - this ratio is calculated as the quotient of the number of gigawatt-hour of electricity produced by the low-carbon energy sources to the total gigawatt-hour of electricity produced in a country;
- gdp is defined as the real GDP per capita at constant prices from 2010;
- $gini$ is defined as the Gini index regarding disposable income before social transfers; with pensions excluded from social transfers;
- edi is defined as a score given in the EIU Democracy Index ranking;

[3] The use of the fixed effects model generally gives similar results to the model with a random effects specification. The difference is that in the variant with the inclusion of natural gas among the low-carbon energy sources, there is slight negative correlation between the state of democracy and the use of low-carbon energy sources for electricity production. That may suggest that less democratic countries are more willing to the energy transition based on natural gas. Nevertheless, results of the Hausman test suggest that random effects specification is more sustainable for this research and therefore the empirical part do not discuss the fixed effects model's results.

- v_{it} t is a composite error term, and $v_{it} = \alpha_i + u_{it}$;
- i refers to 27 member states of EU and t refers to years 2013-2020.

5. Empirical Analysis

In this part of the paper, the two models discussed earlier will be analysed. As a first step, diagnostics testing multicollinearity will be carried out in both of them. Secondly, Breusch-Pagan test will be run, which allows to check for potential heteroskedasticity problem (Wooldridge, 2013, p. 435). At the end, a proper regression will be carried out, using robust standard errors if necessary. The regression results will be discussed briefly.

5.1. First model – natural gas not considered as the low-carbon source of electricity

Multicollinearity diagnostics

Table 5. presents variance inflation factor (VIF) which shows whether there is a problem of multicollinearity. It is generally assumed that the VIF value of less than 4 for individual variables means that there is no multicollinearity problem, which is exactly what occurs in this case.

Variance inflation factor

	VIF	1/VIF
edi	2.618	.382
gdp	2.614	.383
gini	1.007	.993
Mean VIF	2.08	.

Table 5. Multicollinearity diagnostics for the first model.

Breusch-Pagan test

From the standard regression model, which looks like this:

$$lcep_{t+1} = \beta_0 + \beta_1 gdp + \beta_2 gini + \beta_3 edi + \alpha_i + u_{it}$$

and where α_i is an individual specific error term, uncorrelated with the explanatory variables, the following model is derived:

$$\hat{u}_{it}^2 = \pi_0 + \pi_1 gdp + \pi_2 gini + \pi_3 edi + e_{it}$$

The statistical hypotheses are as follows:

$$H_0\colon \pi_1 = 0 \cap \pi_2 = 0 \cap \pi_3 = 0 \ \ (homescedasticity)$$

$$H_1\colon \pi_1 \neq 0 \cup \pi_2 \neq 0 \cup \pi_3 \neq 0 \ \ (heteroscedasticity)$$

The results of this Breusch-Pagan test are presented in the Table 6.

uhat2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	0	0	2.68	.008	0	0	***
gini	0	0	2.27	.024	0	.001	**
edi	-.001	.001	-1.11	.267	-.003	.001	
Constant	-.002	.007	-0.32	.746	-.016	.012	

Mean dependent var	0.003	SD dependent var	0.007
R-squared	0.069	Number of obs	216
F-test	5.237	Prob > F	0.002
Akaike crit. (AIC)	-1565.476	Bayesian crit. (BIC)	-1551.975

**** p<.01, ** p<.05, * p<.1*

Table 6. Breusch-Pagan test results for the first model.

In this case the explanatory variables are jointly significant, as seen from the model's F-test, where p-value = 0.002 < 0.05. This means that the null hypothesis of homoscedasticity is rejected. Heteroskedasticity implies that the standard errors need to be adjusted, therefore robust standard errors will be used in the final regression.

Results and interpretation of the final model (natural gas excluded)

Regression results

lcep_f	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	7.15e-06	2.50e-06	2.87	.004	0	0	***
gini	-.005	.006	-0.92	.356	-.016	.006	
edi	-.006	.027	-0.22	.826	-.058	.046	
Constant	.54	.196	2.76	.006	.156	.923	***

Mean dependent var	0.495	SD dependent var	0.223
Overall r-squared	0.089	Number of obs	216
Chi-square	19.035	Prob > chi2	0.000
R-squared within	0.146	R-squared between	0.087

**** p<.01, ** p<.05, * p<.1*

Table 7. Results of the final regression (natural gas excluded), random effects specification.

In the above model, which includes robust standard errors, two of the explanatory variables do not affect the explained variable. Variables $gini$ and edi are not statistically significant. Coefficient corresponding to the variable gdp is equal to $7.15 * 10^{-6}$. It can be interpreted as follows: 1 USD increase in GDP per capita is associated with $7.15 * 10^{-6}$ increase in the share of low-carbon energy source used for electricity production. At first glance this may not seem much, but it is important to remember that the dependent variable is an index that takes values from 0 to 1. If GDP per capita increases, for example, by $10,000, there will be an average increase in the share of low-carbon energy sources used for electricity production by

0.0715, which is over 7 percentage points. In other words, the wealth of a country's population is reflected in the energy transition.

The hypothesis formulated in the theoretical framework section has been only partially confirmed. If low-carbon energy sources are defined as nuclear energy, renewable energy and energy derived from biofuels, then national wealth influence the share of low-carbon energy sources used in electricity production in EU member states, while economic inequality and the state of democracy do not influence it.

5.2. Second model - natural gas considered as the low-carbon source of electricity and included in the analysis

Multicollinearity diagnostics

Table 8. presents variance inflation factor (VIF) which shows whether there is a problem of multicollinearity. It is generally assumed that the VIF value of less than 4 for individual variables means that there is no multicollinearity problem, which is exactly what occurs in this case.

Variance inflation factor

	VIF	1/VIF
edi	2.618	.382
gdp	2.614	.383
gini	1.007	.993
Mean VIF	2.08	.

Table 8. Multicollinearity diagnostics for the second model.

Breusch-Pagan test

From the standard regression model, which looks like this:

$$glcep_{t+1} = \beta_0 + \beta_1 gdp + \beta_2 gini + \beta_3 edi + \alpha_i + u_{it}$$

and where α_i is an individual specific error term, uncorrelated with the explanatory variables, the following model is derived:

$$\hat{u}_{it}^2 = \pi_0 + \pi_1 gdp + \pi_2 gini + \pi_3 edi + e_{it}$$

The statistical hypotheses are as follows:

$$H_0\colon \pi_1 = 0 \cap \pi_2 = 0 \cap \pi_3 = 0 \ (homescedasticity)$$

$$H_1\colon \pi_1 \neq 0 \cup \pi_2 \neq 0 \cup \pi_3 \neq 0 \ (heteroscedasticity)$$

The results of this Breusch-Pagan test are presented in the Table 9.

Linear regression

g_uhat2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	0	0	-3.40	.001	0	0	***
gini	-.001	.001	-1.81	.072	-.002	0	*
edi	.015	.004	3.57	0	.007	.024	***
Constant	-.057	.036	-1.57	.118	-.128	.014	
Mean dependent var		0.008	SD dependent var			0.033	
R-squared		0.073	Number of obs			216	
F-test		5.562	Prob > F			0.001	
Akaike crit. (AIC)		-867.127	Bayesian crit. (BIC)			-853.626	

*** *p<.01*, ** *p<.05*, * *p<.1*

Table 9. Breusch-Pagan test results for the second model.

In this case the explanatory variables are jointly significant, as seen from the model's F-test, where p-value = 0.001 < 0.05. This means that the null hypothesis of homoscedasticity is rejected. Heteroskedasticity implies that the standard errors need to be adjusted, therefore robust standard errors will be used in the final regression.

Results and interpretation of the final model (natural gas included)

Regression results

glcep_f	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	1.21e-05	5.95e-06	2.04	.042	0	0	**
gini	-.009	.007	-1.23	.22	-.023	.005	
edi	-.123	.104	-1.19	.236	-.327	.081	
Constant	1.712	.58	2.95	.003	.575	2.849	***
Mean dependent var		0.738	SD dependent var			0.256	
Overall r-squared		0.088	Number of obs			216	
Chi-square		13.179	Prob > chi2			0.004	
R-squared within		0.170	R-squared between			0.083	

*** *p<.01*, ** *p<.05*, * *p<.1*

Table 10. Results of the final regression (natural gas included), random effects specification.

In the second model, which as well as the first one uses robust standard errors, findings are similar to the first model. Variables $gini$ and edi are not statistically significant, while coefficient corresponding to the variable gdp is equal to $1.21 * 10^{-5}$. It can be interpreted as follows: 1 USD increase in GDP per capita is associated with $1.21 * 10^{-5}$ increase in the share of low-carbon energy source used for electricity production. Again, it is useful to give an example based on larger numbers for a better visualisation. If GDP per capita increases by 10,000 USD, there will be an average increase in the share of low-carbon energy sources used for electricity production by 0.121, which is over 12 percentage points.

Once again, the hypothesis formulated in the theoretical framework section has been only partially proven. If low-carbon energy sources are defined as the energy derived from natural gas, nuclear energy, renewable energy and energy derived from biofuels, then national wealth influence the share of low-carbon energy sources used in electricity production in EU member states, while economic inequality and state of democracy do not influence it.

What is important to highlight, the effect of including natural gas as low-carbon source of energy is that the correlation between the wealth of a society and the stage of the energy transition is even higher.

6. Discussion and overview of the European climate policy

The results of the empirical analysis confirm the conjecture of the presumptions derived from literature review that the wealth of a society, expressed by GDP per capita, can affect the share of low-carbon energy sources used for electricity production in EU member states. Establishing a separate model that additionally includes natural gas as the low-carbon energy source, which is in line with the EU's policy practice of using natural gas as a transition fuel, shows an even greater effect. The other two variables, the state of democracy and the economic inequality, appeared to have no impact on the share of low-carbon energy sources used for electricity production for the countries covered by the study.

This section of the paper explores two issues. The first one is a debate on why, in the European Union, two of the factors discussed are not reflected in the transformation of the energy production system to a greener one. The second, explores what are the policy implications for the European Union of the fact that the rate of electricity production from the low-carbon energy sources, varies from country to country, and it is correlated to the affluence of societies in particular member states.

6.1. EU policy framework as a partial explanation for the findings of the research

While the inclusion of economic inequality in the research was mainly motivated by theoretical considerations and driven by scientific curiosity, the inclusion of an indicator measuring the state of democracy was based on other empirical study. It is important to consider why, in contrast to the study by Clulow and Reiner (2022), democracy has not proven to be relevant to energy transition. The difference may be caused by the selection of countries for the study. In this study, EU member states are used, while Clulow and Reiner (2022) referred to various countries across the world. The countries associated within the EU, although they differ from each other, are either flawed democracies or full democracies. There are no authoritarian or semi-authoritarian regimes (Economist Intelligence Unit, 2013-2021). Moreover, the European Union is a very unique organisation in a global context, due to the shared policies involving the member countries through the initiative of the European Commission.

In 2015 the “energy union” strategy was launched, providing a plan of extensive range of operations aiming to integrate the common energy system even further, and set up even more ambitious climate goals than before, simultaneously by extending the competence of EU authorities to monitor the energy systems of the member states, including their emissions (European Commission, n.d.). We must also remember the ETS supported by the ESR, as another important regulatory factor. Based on the total amount of certain greenhouse gases that can be emitted by the operators covered by the system, a cap is set, limiting amount of emissions. Operators buy or receive emissions allowances, which they can trade with one another. When the limit is exceeded, fines are imposed. Since the ETS covers many electricity generating facilities, it should be assumed that it is not neutral for the energy policy decisions of particular countries, related to how they produce electricity. This specific EU regulatory framework may result in the effect of democratisation, or the potential effect of economic inequalities, on the degree of use of low-carbon energy sources in electricity production being insignificant, in contrast to the assumptions drawn from the literature review.

This can be observed, for example, in the case of Poland. Despite the declining state of democracy during the period studied, as well as the strong pro-carbon lobby in the country (Cienski, 2020) and the aversion to energy transition of the government there (IEEFA, 2022), decarbonisation was progressing. It can be seen on figures 6. and 7. This applies to both the model where natural gas is included as low-carbon source of energy and the model where natural-gas is excluded.

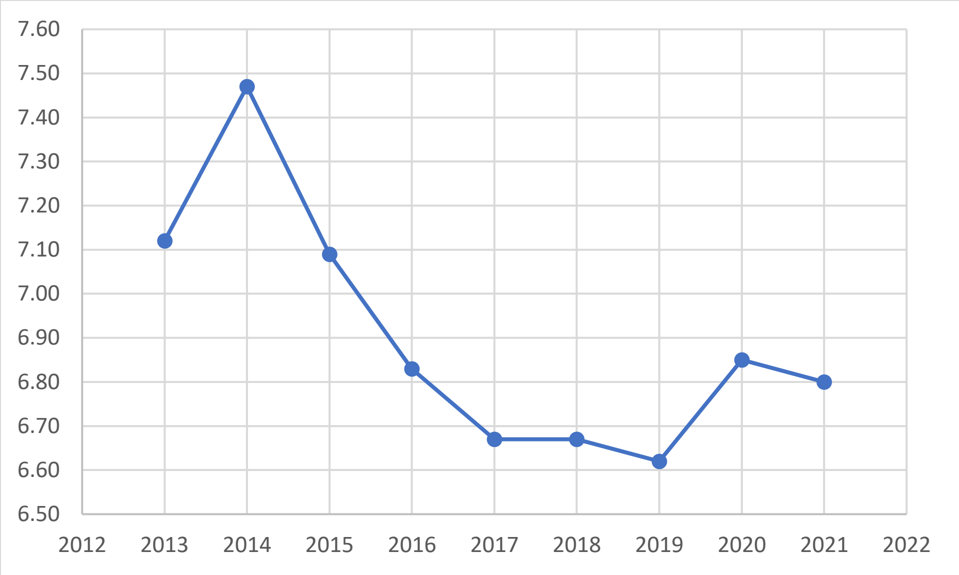

Figure 6. State of Democracy in Poland based on EIU Democarcy Index.

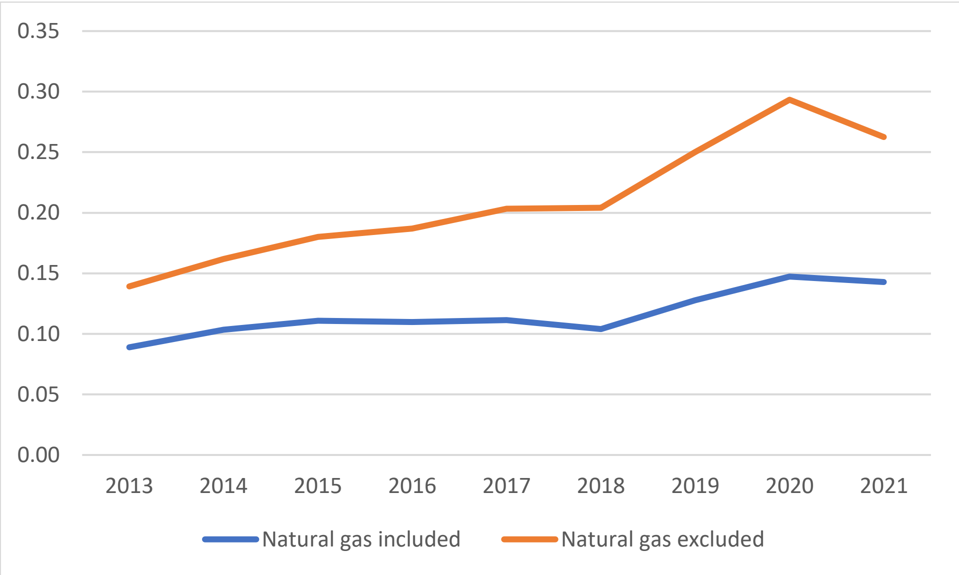

Figure 7. Share of low-carbon energy sources in electricty production in Poland (source: Eurostat).

This may show either the impact of the regulatory framework of European Union or the impact of the GDP per capita growth in Poland at that time, which, as is known from the empirical analysis of this paper, is positively correlated with decarbonisation. The growth of GDP per capita in Poland at 2010 constant prices can be seen in figure 8.

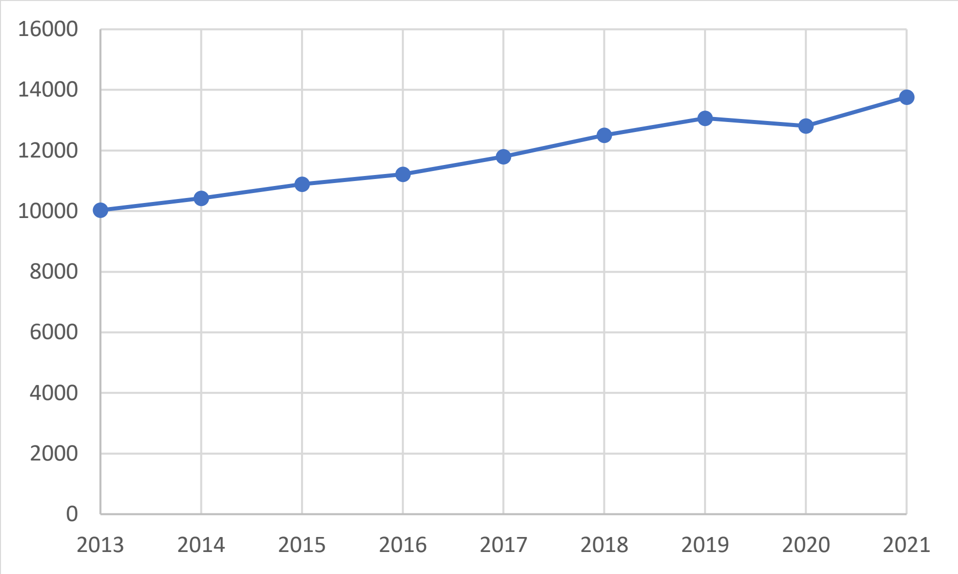

Figure 8. GDP per capita in Poland at 2010 constant prices (source: Eurostat).

To sum up, the EU's policy framework is one of the possible explanations why the state of democracy measured in this research has no influence on the low-carbon electricity production, in contrast to other studies. This case remains open and potentially provides space for further research. The issue of economic inequality had a weaker empirical basis, in view of which its statistical insignificancy in this research can be as well explained by the energy policy of the EU, but there is less justification for this.

6.2. Policy implications of the conducted research

The most important findings of this research is that a rise in GDP per capita at 2010 constant prices by 1000 USD in the EU member states can be associated with 0.7 percentage points increase in share of low-carbon energy sources used for electricity production, when the considered low-carbon energy sources are nuclear, renewable, and biofuels. If one additionally adds natural gas as a low-carbon energy source to the equation, which is in line with EU policy practice, then a rise in GDP per capita at 2010 constant prices by 1000 USD in the EU member states can be associated with 1.2 percentage points increase in the share of low-carbon energy sources used for electricity production.

Even despite the Russian invasion of Ukraine, and the restriction of economic exchange with Russia, which has been Europe's major natural gas supplier, the EU is continuing to promote natural gas as a transition fuel. For example, in July 2022 the European Parliament established the law enabling to label investments in gas power plants as climate-friendly within the regulatory framework of the EU "taxonomy" (Abnett, 2022). Simultaneously, the EU countries are rebuilding their gas imports, by cooperating with Norway or non-European countries (Breugel, 2023). Natural gas will continue to play a major role in the EU's energy transition. However, as the results of this study show, between 2013 and 2021, the transformation with gas among the EU countries, was associated with GDP per capita more strongly than that with only other low-carbon energy sources included. Simply including natural gas as low-carbon is not enough to stimulate the energy transition in less affluent member states.

In order to summarize, the findings of this research are showing the positive correlation between GDP per capita and electricity production with the use of low-carbon energy sources. The correlation is even stronger when natural gas is considered to be low-carbon. The policy recommendation that can be derived from the results is that investing in EU programmes directed towards helping the less affluent countries in the energy transition may be potentially very effective. Figure 9. graph illustrates how energy-related EU funding has been allocated so far. Allocation considerations are of course very complex, but it is noticeable that the wealth of the country was certainly not the main criterion.

In contrast to considering further investing directly in the energy transition of the least wealthy EU countries, promoting natural gas plants will be less effective tool, if the policy goal is to achieve an equal energy transition among the EU member states. Basing on the findings derived from this research, it is in favour of the richest countries of the EU mostly.

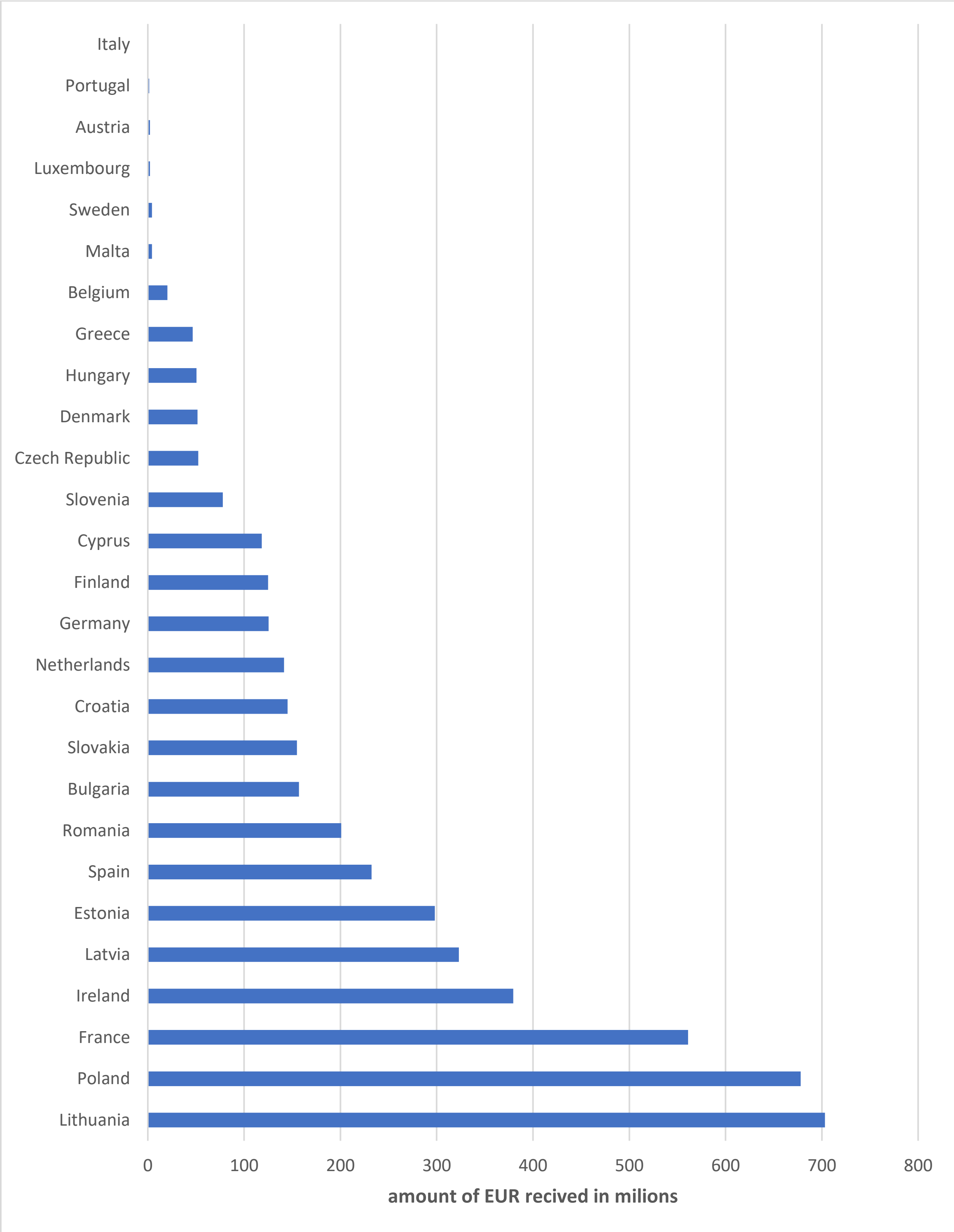

Figure 9. Amount of funds received under EU energy projects for the period 2014 – 2021 (Source: European Commission Financial Transparency System.

7. Conclusions

This paper's aim was to answer the following question: "Do national wealth, income inequality and state of democracy have an influence on the share of low-carbon energy sources in electricity production across EU countries faced with EU climate policy?" The literature regarding national wealth suggested that in fact the affluence of particular countries' citizens is influencing societies' attitude towards the climate change mitigation and therefore indirectly the energy policy expressed as the share of low-carbon energy sources used for electricity production. The findings of the literature were mixed. There were arguments for positive correlation, as well as for negative correlation. This research clearly showed that there is such relationship, and that change in GDP per capita is influencing the energy transition in electricity production of a specific country positively. Including natural gas in the second model as low-carbon, additionally to the energy sources like nuclear, renewable and biofuels, not only confirmed the findings of the first model, but also showed that in such circumstances the effect was even stronger.

Two other factors considered by the research question were inequality inspired by theoretical considerations of the paper by Kempf and Rossignol (2005) and the state of democracy based on the empirical findings of Clulow and Reiner (2022). These factors however, turned out to be statistically insignificant. It should be noted that the papers referred to countries on a global scale, which is an important notion regarding fact, that the last part of the research question assumes facing the findings with the EU climate policy.

At this point, it need to be highlighted that this paper covered only 27 member states of the European Union. It is highly probable that the lack of results confirming the above part of the literature is an effect of common energy policies adopted by the EU authorities. Regulations, directives, special funds devoted to the energy transition, all of these are the factors that smooth out differences between member states in terms of low-carbon electricity production. Nonetheless, these differences may still be considerably large. To give an example, in 2021 over 70% of electricity produced in Poland was made with the use of solid fossil fuels (mostly different types of coal), while in Sweden over 67% of electricity was generated from the renewable energy[4].

[4] Calculations based on Eurostat data retrieved march 21, 2023, from https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_PEH__custom_5640002/default/table?lang=en.

The EU should continue to work towards the decarbonisation of the electricity generation sector in all member states so that these differences disappear. According to the results of this study, the country's wealth is positively correlated with the energy transition in this area. Because of this fact, EU authorities should promote policies supporting financially transition process in less affluent member states even further. Simultaneously, the correlation when natural gas is included among the low-carbon energy sources is slightly bigger. It implies, that promoting natural gas as a transition fuel, which is in line with the current EU policy practice, is rather more helpful to the wealthier countries. Policymakers should mind that fact, as this is another argument supporting the idea that future climate policies should be guided by the interests of less wealthy countries.

Limitations of this study are due to the fact that some of the factors influencing energy transition have not been taken into account. These include access to initial energy resources within a country, access to energy generation technology, or certain cultural issues. Despite these limitations, the results of this study can still provide a general overview of the situation in the European Union and serve the policymakers in designing a framework to stimulate an even energy transition process among the member states.

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Appendix 1 - Results of the models without a time lag

Regression results

lcep	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	8.63e-06	2.45e-06	3.52	0	0	0	***
gini	-.001	.004	-0.24	.813	-.009	.007	
edi	-.051	.029	-1.76	.079	-.108	.006	*
Constant	.699	.213	3.28	.001	.281	1.118	***

Mean dependent var	0.487	SD dependent var	0.224
Overall r-squared	0.074	Number of obs	243
Chi-square	21.466	Prob > chi2	0.000
R-squared within	0.151	R-squared between	0.071

**** p<.01, ** p<.05, * p<.1*

Table 11. Results of the regression (natural gas excluded), random effects specification, without the time lag.

Regression results

glcep	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	1.27e-05	6.27e-06	2.03	.042	0	0	**
gini	-.003	.007	-0.40	.693	-.017	.011	
edi	-.181	.132	-1.37	.171	-.441	.078	
Constant	1.925	.719	2.68	.007	.515	3.335	***

Mean dependent var	0.730	SD dependent var	0.261
Overall r-squared	0.083	Number of obs	243
Chi-square	12.500	Prob > chi2	0.006
R-squared within	0.186	R-squared between	0.073

**** p<.01, ** p<.05, * p<.1*

Table 12. Results of the regression (natural gas included), random effects specification, without the time lag.

Appendix 2 – Results of the models with a fixed effects specification

Regression results

lcep_f	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	9.35e-06	2.39e-06	3.90	0	0	0	***
gini	-.004	.004	-1.01	.313	-.011	.003	
edi	.001	.027	0.04	.969	-.052	.054	
Constant	.373	.244	1.53	.129	-.109	.855	

Mean dependent var	0.495	SD dependent var	0.223
R-squared	0.149	Number of obs	216
F-test	10.839	Prob > F	0.000
Akaike crit. (AIC)	-665.316	Bayesian crit. (BIC)	-651.815

**** p<.01, ** p<.05, * p<.1*

Table 13. Results of the regression (natural gas excluded), fixed effects specification.

Regression results

glcep_f	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gdp	1.7e-05	4.30e-06	3.95	0	0	0	***
gini	-.007	.007	-1.00	.318	-.019	.006	
edi	-.128	.049	-2.64	.009	-.224	-.032	***
Constant	1.54	.439	3.50	.001	.673	2.407	***

Mean dependent var	0.738	SD dependent var	0.256
R-squared	0.174	Number of obs	216
F-test	13.022	Prob > F	0.000
Akaike crit. (AIC)	-411.978	Bayesian crit. (BIC)	-398.477

**** p<.01, ** p<.05, * p<.1*

Table 14. Results of the regression (natural gas included), fixed effects specification.

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