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Article

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ENERGY TRANSITION AND SUSTAINABLE DEVELOPMENT AT THE LEVEL OF THE EUROPEAN UNION

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Abstract

The energy transition is a priority for the European Union, both in terms of reducing greenhouse gas emissions and reducing its dependence on imported fossil fuels. The European Union is at the forefront of the fight against climate change caused by greenhouse gas emissions. This article presents the relationship between greenhouse gas emissions and the main factors that directly affect the growth of greenhouse gas emissions, such as GDP per capita or greenhouse gas emissions per capita in the previous period (t-1). To conduct this study, a panel data model was used with statistical data provided by EUROSTAT for the 27 Member States of the European Union for the period 2005-2020. Data processing was performed using the econometric program Eviews 8. The research results show that in developed countries, where GDP per capita is high, greenhouse gas emissions are also high. Therefore, the energy transition is a necessity, especially since these countries also have the financial resources to support it.

Keywords: energy transition, greenhouse gas emissions, green energy, sustainable development, European Union.

JEL Classification: O13, O44, Q01, Q42, Q51, Q53.

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Introduction

The 21st century brings a number of challenges at the global level, both in terms of numerical population growth and economic growth at the global level and, implicitly, in the increase in greenhouse gas emissions. The world population is growing rapidly, recording a billion inhabitants in each decade of the 21st century (the seventh billion in 2011 and the eighth billion in 2022) (World Bank, 2022a). Accelerated population growth also requires economic growth to meet the demand for goods and services (global GDP was \$33.83 trillion in 2000 and \$96.1 trillion in 2021 (World Bank, 2022b). Under these conditions, energy plays a special role in economic growth (Ozturk, 2010), the consumption of energy resources is increasing, and the emission of greenhouse gases is still high (Chiu and Chang, 2009). To protect the planet, humanity must find optimal solutions to meet these challenges/problems. Among the causes that contribute to climate change, greenhouse gases play an important role. Therefore, reducing the consumption of fossil fuels and replacing them with renewable energy can be a solution. According to Bhattacharya et al. (2016), who studied the impact of renewable energy consumption on economic growth in the main countries that consume renewable energy, renewable energy consumption has a significant positive impact on economic performance.

Climate change is a global challenge that has both global and regional impacts. According to the Intergovernmental Panel on Climate Change (IPCC, 2014), greenhouse gas emissions could be reduced by using renewable energy sources. Renewable energy sources are less polluting than fossil fuels (Wei, Patadia and Kammen, 2010; IPCC, 2014). An important initial signal regarding climate change was the Kyoto Protocol (UNFCCC, 1997), which entered into force in 2005 and committed signatories to maintain greenhouse gas emissions at 1990 levels by 2012. At the Paris conference in 2015 (UNFCCC, 2015), agreement was to be reached on the goal of limiting global warming to less than 2°C above preindustrial levels. The agreement called for net-zero greenhouse gas emissions to be achieved in the second half of the 21st century. The IPCC's sixth report concludes that greenhouse gas emissions must be reduced by 43% by 2030 to meet the goal of limiting global warming to 1.5 °C, and that the energy sector will play an important role in this transition (IPCC, 2022). The European Green Deal (European Commission, 2019) presents a new growth strategy whose main goal is to achieve the neutrality of the European Union (EU) in terms of net greenhouse gas emissions by 2050, decoupling economic growth from resource consumption. Sweden was the first EU country to announce 2045 as the target for achieving climate neutrality, and in 2021 Germany announced the same year as the target for achieving climate neutrality. German studies exclude nuclear power as an option to achieve climate neutrality, just as carbon capture and storage are not desired (Wiese, Thema and Cordroch, 2022). Between 1990 and 2018, the EU reduced its GHG emissions by 23% while the economy grew by 61%. More than 75% of GHG emissions in the EU come from energy production and use in different sectors of the economy, making energy efficiency and effectiveness a priority. It is also necessary to develop an electricity sector based on renewables, coal phase-out, and gas decarbonisation (European Commission, 2019).

Strategies pursued by several countries to reduce greenhouse gas emissions include increasing energy efficiency or using renewable energy sources, reducing fossil fuel resources, and replacing them with renewable energy sources that have lower energy content compared to fossil fuels (Chiu and Chang, 2009). Economic growth significantly promotes the long term use of renewable energy in Europe in (Al-Mulali, Ozturk and Lean,

2015), and the increased use of renewable energy would improve the overall state of the environment in the Organization for Economic Cooperation and Development (OECD) countries (Alam and Murad, 2020).

The geopolitical events of 2022, namely the conflict between Russia and Ukraine, have also had a major impact on the energy market, with fatal consequences for everyone, not just Europe. Therefore, the green energy transition becomes the only way to ensure sustainable, secure, and affordable energy worldwide at the same time (European Commission, 2022a). REPowerEU provides a plan to phase out fossil fuel imports from Russia before 2030, accelerating the transition to green energy. The REPowerEU plan can become effective if the proposals of the “Fit for 55” package, which envisages a 30% reduction in natural gas consumption by 2030, are implemented (European Commission, 2022b). On the other hand, the European Union (EU) must find new energy suppliers and increase energy savings and energy efficiency. The European Union will have new opportunities to lead in green technologies and promote sustainable development. Energy is considered an important factor for sustainable development (Khan, Khan and Binh, 2020). The EU supports several research programs on pollution reduction, fossil fuel consumption reduction, and new innovations in renewable energy technologies. In line with the Sustainable Development Goal (SDG) 7 - Renewable and Affordable Energy (EUROSTAT, 2022a), the EU will strongly commit to an equitable and inclusive energy transition. Green industrial policies to promote economic growth are supported by a growing number of countries and regions, including the EU (Kuik, Branger and Quirion, 2019).

In this sense, the objectives of the research are: to identify the main factors influencing the increase of greenhouse gas emissions in the process of energy transition in the European Union; to explain to what extent the identified factors can support the energy transition towards a green and sustainable economy; to present how the energy transition towards a renewable and sustainable economy will be able to achieve the main objective of the European Green Deal, namely that the EU achieves neutrality in terms of net greenhouse gas emissions by 2050.

The main objective of the research is to identify the most important factors that influence the increase in greenhouse gas emissions in the course of the energy transition in the European Union.

The novelty of this study lies in the fact that it adopts a macroeconomic approach to energy transition at the level of the 27 EU member countries, highlighting the existence of unique characteristics for each country over the period 2005-2020 and illustrating the impact of certain variables, such as real GDP per inhabitant, energy productivity, share of renewable energy in gross final energy consumption by sector, share of environmental taxes in total tax revenues, on greenhouse gas emissions per capita.

The article is divided into the following parts: In the first section, a literature review is given, analysing the most important and recent studies in the field of energy transition; in the second section, the methodology and data used in the research are presented; in the third section, the research results are presented; and at the end of the article, the conclusions are presented.

1. Review of the scientific literature

The energy transition plays a central role in combating the negative effects of climate change. The process involves moving away from a fossil fuel-based energy regime to one in which renewable sources play an important role in energy production. The energy transition, understood in Schumpeterian terms as "creative destruction," involves complex and multidimensional changes in institutions, infrastructures, technologies, products, and energy production practices (Davidson, 2019).

The energy transition has a long history in human history and reflects far-reaching social changes on a global scale related to industrialisation, urbanisation, and consumer society (Verbong and Loorbach, 2012). In its initial phase, the energy transition was characterised by the transition from wood to coal use and the large-scale electrification of urban and rural regions in the late 19th century, which had profound social, technological, and geographic implications. The current phase is characterised by several features that are important for the dynamics and intensity of the energy transition. First, *the acceleration* of the energy transition, which includes the complex interaction between different types of technologies, the transformation of business models, the fierce competition between key economic and political actors, and the major challenges related to the operation and performance of the energy sector (Grubler, 2012; Markard, 2018; Yan, 2022). Second, *the uncertainty of the context* in which the energy transition is taking place adds structural vulnerabilities created by the technological complexity of the fossil fuel-based system, the depletion of resources, the geopolitical instability and increase in interdependencies between producers and consumers, the large costs and price fluctuations in the international market, the negative impacts on the natural environment, and the large contribution to climate change (Leach, 1992; Verbong and Loorbach, 2012; Engels, Kunkis and Altstaedt, 2020). Third, the patterns of spatial distribution of energy resources, production, and consumption, as well as the varying participation of national governments in sustainable energy policies, create *a new geography* of trade and investment flows around the world (Basmakov, 2007; Bridge et al., 2013).

Scientific studies dealing with the energy transition emphasise the long-term dynamics between economic development (measured by GDP per capita), energy consumption, and pollution, which is theoretically formalised by the environmental Kuznets curve. The inverted U-shaped curve explains the negative impact of economic growth on the environment through increased emissions up to a certain threshold. Beyond this threshold, the environmental impact of economic growth decreases, usually due to the introduction of innovative new technologies or the widespread use of renewable energy sources (Saqib and Benhmad, 2021; Verbič, Satrović and Muslija, 2021). Applied to the European continent, the Kuznets hypothesis highlights several correlations between carbon emissions and determinants such as energy consumption, income, and international trade, which together define variants of the Kuznets curve originally identified in the literature (Ketenci, 2021).

The sociotechnical transformation of the energy system refers to the adoption of a comprehensive systemic view of the components of the natural environment, individuals, and organisations to support sustainable development patterns in the context of anthropogenic climate change and to determine future development trends (Li et al., 2015; Kern and Markard, 2016). A basic premise in this approach is the complementarity of natural and human resources, capital and investment, products, and services as favourable

or constraining factors for the creation and diffusion of new technologies and for the stability of the energy system (Markand and Hoffmann, 2016).

The "climate urgency" on the one hand and the limited progress in achieving the energy transition and reducing the magnitude of climate change in the future on the other hand have brought the concept of *energy efficiency* to the attention of scientists and policy makers (Grubler, 2012). The concept emphasises the dependence of energy efficiency and conservation on "green finance," technology and innovation, and legal regulation as key elements of environmental protection (Nosheen, Iqbal and Abbasi, 2021). The energy market plays a major role in the energy transition by setting parity prices for renewable resources, justifying fossil fuel abandonment, and redirecting energy demand to green sources by imposing taxes on carbon emissions (Fernandez, 2018; Adamczyk and Graczyk, 2020). *Carbon emissions intensity* refers to the assessment of the amount and type of pollutants in the context of ensuring climate neutrality and promoting low-emission economies as fundamental sustainable development goals (Usman et al., 2021). *Energy productivity* is negatively affected by globalisation, which contributes to environmental degradation, but is supported by innovations that improve the quality of the environment (Ahmad et al., 2021). The sustainable energy transition exacerbates social inequalities through *differential access to energy* (Bartiaux et al., 2019). Material deprivation, low individual incomes, and energy poverty challenge the concept of *just transition*. Equity as an outcome of systemic change requires both mechanisms that create public benefits and new infrastructures and practices of sociotechnical systems (Sareen and Haarstad, 2020). *Energy policy* reflects the role of states in ensuring the "decarbonised future" (Marquardt and Nasiritousi, 2022; Sovacool and Griffiths, 2020) by respecting the internationally agreed Sustainable Development Goals, particularly those of "access to affordable, reliable, sustainable, and modern energy for all" (EUROSTAT, 2022a).

At the level of the European Union, the energy transition is a priority for the environment and sustainable development policy. The European Union, which ranks third in the world in terms of greenhouse gas emissions after China and the United States (European Environment Agency, 2015), has proposed climate neutrality by 2050 as a strategic goal. In addition to the structural difficulties that characterise the global energy transition, in the case of the EU, there is a diversity of energy transition pathways at the Member State level (Sarrica et al., 2016), due to economic history and development models promoted by Member States. More recently, the current energy crisis, caused by the political decision to end the dependence of EU countries on Russian gas and the identification of alternative energy sources, especially environmentally friendly resources (wind, solar, nuclear, or hydrogen), has complicated the geopolitical context and international relations. The energy mix at the member state level shows great differences in terms of the share of renewable resources, which is higher in the northern European countries than in the other European regions. Greenhouse gas emissions are higher in Southern and Central Europe, with an increasing trend in the future (EUROSTAT, 2020a). The different position in the energy transition process, the availability of energy resources, and the efficiency of local and regional governance models are the key factors explaining the relationship with EU environmental policy goals, which range from rapid adoption and full implementation of European directives (Netherlands, Denmark, Spain) to ambivalence (France), and to resistance and contestation (Germany, Poland, Romania, Bulgaria) (Solorio and Joergens, 2020).

2. Research methodology

The transition to a green economy is a necessity given the current crises, economic, human, environmental, social, medical, energy, and the excessive consumption of resources on which economic growth has been based. The entire economic system needs to be rethought, and the functioning of the economy must be based on the principle of sailboats powered by ecological processes and renewable, recyclable, and reusable resources, rather than on natural resources that are limited and exhaustible and mostly non-renewable. At the global level, the emphasis is on eco-efficiency and a sustainable production system, and the transition to a sustainable energy system based on efficiency and renewable energy has required the replacement of an entire complex system based on high consumption of natural resources. The green economy is the solution for healthy, prosperous, and clean living, and economic policy must establish a very clear basic ecological framework for the market, aimed at: drastically reducing emissions harmful to the climate, preserving natural landscapes in rural areas, protecting the diversity of the planet, stopping the production of nuclear waste, etc. The transition from a waste society to a circular economy will create new jobs, replace extractive industries, create economic and social stability, ensure a healthier and cleaner environment, generate energy from wind turbines instead of coal mines, and build cities for people, not cars. The green economy will no longer conflict with its support system, i.e., the planet's ecosystem, but will be able to sustain economic progress for a long time (Vîrjan, D., 2011).

The 27 Member States of the European Union existing in 2020 were considered for the study. Statistical data were collected for the period 2005-2020 for a set of indicators included in the seventh section of the Sustainable Development Goals of the UN: Renewable and Affordable Energy (EUROSTAT, 2022b). Among the indicators included in this section, we selected for the data panel the independent variables such as: GDP per capita, GHG emissions per capita in the previous period, energy productivity, share of renewable energy in gross final energy consumption by sector, and share of environmental taxes in total tax revenues, which we assumed to have a large impact on the increase of GHG emissions.

The starting point for the selection of the independent variables was to examine the extent to which the indicators that are part of the seventh section of the Sustainable Development Goals (SDG 7) of the Agenda UN - Renewable and Affordable Energy - can influence the reduction of greenhouse gas emissions and primary energy consumption, and the extent to which the energy transition causes a reduction in greenhouse gas emissions and encourages investment in renewable and less polluting energy. First, we tested the regression model with the following independent variables: energy productivity; the share of environmental taxes in total tax revenues; the share of renewable energy in gross final energy consumption by sector; the dependence on energy imports; the population unable to properly heat their homes, according to poverty status, but after processing the data, the model was not valid and statistically significant, and then we introduced the indicator GDP per capita, because it is the most important indicator of economic growth and especially in energy-consuming countries; we also introduced the consumption of greenhouse gas emissions from the previous year, we kept the weight of environmental taxes and the share of renewable energy in gross final consumption because they are two important variables in the process of energy tension, and we removed the dependence on energy imports and the population that is not able to heat their homes due to their poverty status. In order to arrive at the

regression model presented in the econometric analysis section, several experiments and tests were conducted.

Several research papers have used regression as a research method in different forms. For example, the panel quantile regression of Khan, Khan and Binh (2020) was used to study the heterogeneity of renewable energy consumption, carbon dioxide emissions, greenhouse gas emissions, and financial development for 192 countries. An empirical panel data model was used by Chiu and Chang (2009) for all 30 OECD member countries for a period between 1996 and 2005 to investigate the threshold effect of renewable energy share in reducing GHG emissions. Ma et al. (2015) use meta-regression as a research method to determine consumers' willingness to pay for renewable energy. To achieve the proposed objectives, we formulated the following hypotheses:

- H1: Economic growth leads to an increase in greenhouse gas emissions in the member states of the European Union;
- H2: GHG emissions per capita in the previous period (t-1) support a further increase in GHG emissions;
- H3: The share of renewable energy in gross final energy consumption by sector leads to energy transition and sustainable development by reducing greenhouse gas emissions.

3. Results and discussion

To analyse the effects of several variables on GHG emissions, we used a panel data model because we wanted to highlight the existence of unique characteristics of each unit/country that are constant over time, and used the econometric program Eviews 8. All variables are from the Eurostat database, which contains annual data for the period 2005-2020 for 27 European countries that are members of the EU (balanced panel data). We used a regression equation in which GHG (GHG emissions per capita in the current period) is the dependent variable and the other variables are the independent variables: GHG (-1) (GHG emissions per capita in the previous period), ENERGPORD (energy productivity), LOG (GDP per capita); RENEW (share of renewable energy in gross final energy consumption by sector), TAX (share of environmental taxes in total tax revenues) (Table no. 1).

Table no. 1. Explanation of dependent variable and independent variables

Variable coding	Variable name	Unit of measurement	Source	Variable type
GHG	Greenhouse Gas Emissions per capita	Million tonnes	Eurostat	Explained
ENERGPORD	Energy productivity	KGOE	Eurostat	Explanatory
LOG(GDP)	GPD-ul per capita	Euro	Eurostat	Explanatory
RENEW	Share of renewable energy in gross final energy consumption by sector	Percentage	Eurostat	Explanatory
TAX	Share of environmental taxes in total tax revenue	Percentage	Eurostat	Explanatory

C(1) – represents the constant of the model (intercept); C(2), C(3), C(4), C(5), C(6) – represent the elasticity coefficients of the dependent variables when the independent variables change. Our results based on the panel model show that the model is valid, coherent, and autoregressive in the studied period after the adjustments made in the Eviews 8 program; all coefficients of the considered independent variables are statistically significant, indicating that all these variables are representative and have explanatory power for the change in the dependent variables.

The regression equation has the form:

$$GHG_{it} = C(1) + C(2)*GHG(-1)_{it(t-1)} + C(3)*ENERGPROD_{it} + C(4)* LOG (GDP)_{it} + C(5)*RENEW_{it} + C(6)*TAX_{it} + \alpha_i + u_{it} \tag{1}$$

respectively,

$$GHG_{it} = -4.21 + 0.75*GHG(-1)_{it(t-1)} - 0.2*ENERGPROD_{it} + 0.86* LOG (BIP)_{it} - 0.06*RENEW_{it} + 0.09*TAX_{it} + \alpha_i + u_{it} \tag{2}$$

Where:

i - country ($i = \overline{1,27}$);

t - year ($t = \overline{1,16}$);

α_i - fixed cross-sectional coefficients for each country i (given in the table no. 2 for each country);

u_{it} - represents the random error with respect to country i , year t .

Table no. 2. Panel data estimation output

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.209585	2.680242	-1.570599	0.1171
GHG(-1)	0.751463	0.032163	23.36423	0.0000
ENERGPROD	-0.198973	0.044945	-4.427007	0.0000
TAX	0.088224	0.043238	2.040412	0.0420
RENEW	-0.056255	0.009223	-6.099290	0.0000
LOG(GDP)	0.855917	0.293727	2.913989	0.0038
Fixed Effects (Cross)				
BELGIUM--C	-1.044892			
BULGARIA--C	-0.172635			
CZECHIA--C	0.113947			
DENMARK--C	1.304810			
GERMANY--C	-0.194655			
ESTONIA--C	1.826570			
IRELAND--C	0.602883			
GREECE--C	-0.004327			
SPAIN--C	-0.719295			
FRANCE--C	-0.800022			
CROATIA--C	0.001815			
ITALY--C	-0.502398			
CYPRUS--C	0.290007			
LATVIA--C	0.390311			
LITHUANIA--C	0.452685			
LUXEMBOURG--C	1.509011			
HUNGARY--C	-0.895197			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MALTA--C	-2.125460			
NETHERLANDS--C	-1.150955			
AUSTRIA--C	0.545120			
POLAND--C	-0.164663			
PORTUGAL--C	0.326495			
ROMANIA--C	-0.397846			
SLOVENIA--C	-0.054397			
SLOVAKIA--C	-1.312412			
FINLAND--C	1.233018			
SWEDEN--C	0.942480			
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.979369	Mean dependent var	9.836049	
Adjusted R-squared	0.977654	S.D. dependent var	3.888271	
S.E. of regression	0.581240	Akaike info criterion	1.828411	
Sum squared resid	126.0144	Schwarz criterion	2.144768	
Log likelihood	-338.2532	Hannan-Quinn criter.	1.953631	
F-statistic	571.1727	Durbin-Watson stat	1.724348	
Prob(F-statistic)	0.000000			

Source: Own processing based on data from the Eurostat (2022, b)

According to our model, the main independent variables that affect GHG emissions are GHG emissions from the previous period (t-1) and GDP per capita, both of which have a direct impact on emissions from the current period (both explanatory variables have positive coefficients: 0.75 and 0.85, respectively). The value of GHG emissions per capita is autoregressive, since the emissions of the current year depend on those of the previous year, and this dependence is quite clear due to the fact that the variable has a significant coefficient. The independent variable GDP per capita is a variable that has a positive (direct) effect on GHG emissions. Therefore, if there is an expansion of production and economic growth, then it is logical that emissions per capita will increase, which is reflected in the value of the coefficient, which is positive and is 0.855917. Thus, a 1% increase in GDP per capita leads to an estimated increase in GHG emissions of almost 0.86 percentage points. As can be seen from figure no. 1, there is a perfect direct positive correlation between GDP per capita and greenhouse gas (GHG) emissions, and since the coefficient is above 0.8, the correlation is high.

The results of the econometric model confirm the first two hypotheses, namely that economic growth reflected in GDP per capita leads to an increase in GHG emissions, which is verified at the European Union Member State level, and the second hypothesis that GHG emissions per capita from the previous period support a further increase in GHG emissions.

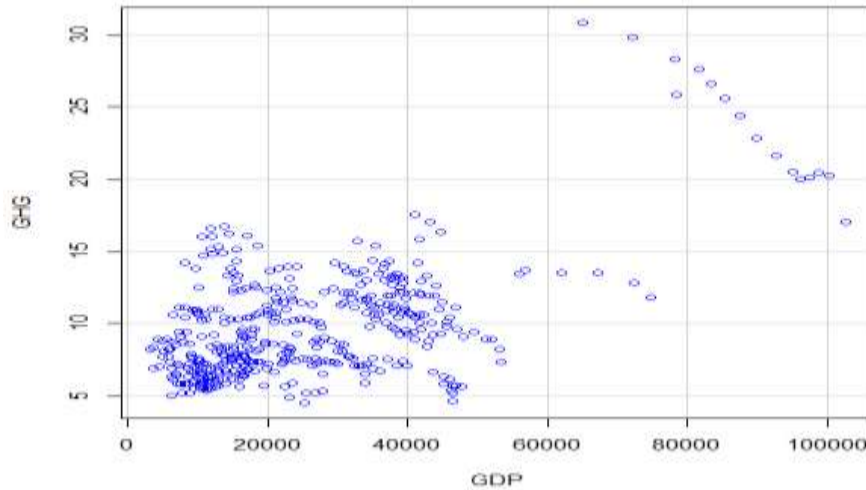


Figure no. 1. Correlation between GHG and GDP

Source: Own processing based on data from Eurostat (2022, b)

Regarding energy production (ENERGPROD), we note that there is an inversely proportional relationship between this independent variable and GHG emissions per capita, i.e., with the increase in energy productivity, emissions are reduced, which is also justified by the value of the coefficient of approximately 0.198973. Thus, energy productivity has a negative impact on GHG emissions in the EU Member States, as a 1% increase in energy resource productivity results in an estimated decrease in emissions of about 0.2 percentage points. As can be seen in figure no. 2, there is a perfect inverse-negative correlation between energy productivity and greenhouse gas emissions, and since the coefficient is less than 0.2, we have a very weak correlation.

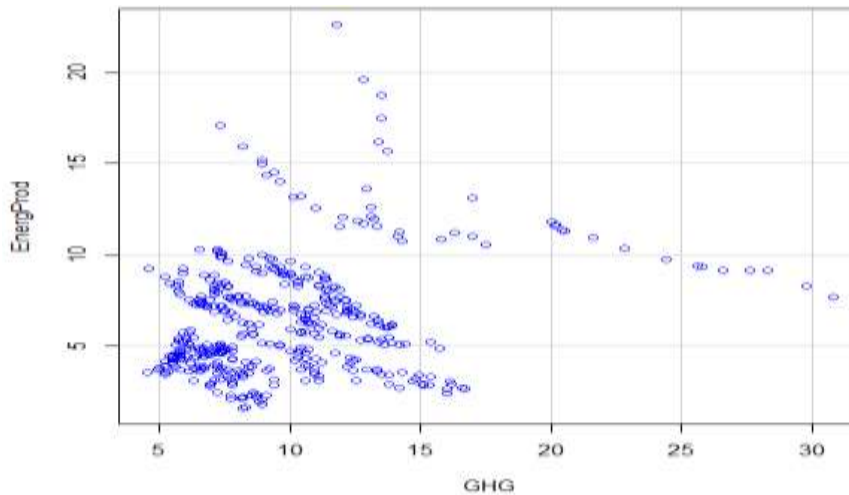


Figure no. 2. Correlation between GHG and ENERGPROD

Source: Own processing based on data from Eurostat (2022, b)

The independent variable, the share of renewable energy in gross final energy consumption by sector (RENEW), is negatively related to GHG emissions, but to a very small extent, so it is estimated that a 1% increase in the share of renewable resources in consumption reduces GHG emissions by about 0.06 percentage points (0.056255). As we can see in figure no. 3, there is a perfect inverse-negative correlation between energy productivity and greenhouse gas emissions, and since the coefficient is less than 0.2, we have a very weak correlation.

The results of the econometric analysis confirm the third hypothesis we started from, namely that the share of renewables in gross final energy consumption by sector leads to energy transition and sustainable development by reducing greenhouse gas emissions.

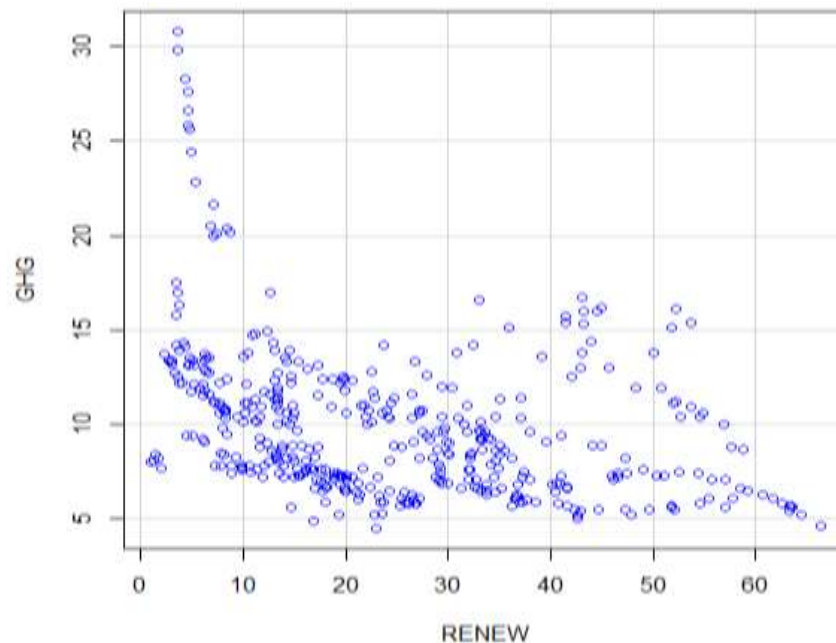


Figure no. 3. Correlation between GHG and RENEW

Source: Own processing based on data from Eurostat (2022, b)

As for the environmental tax's share of total government revenue, it does not appear to have a negative impact on GHG emissions, as expected. The most plausible explanation could be that the level of taxation in the EU Member States, especially in the new Member States of Central and Eastern Europe, is very low, and taxes cannot act as a reduction factor for GHG emissions. Thus, a 1% increase in the share of taxes in government revenues resulted in an estimated increase in emissions of about 0.08 percentage points (0.088224). The relationship between the environmental tax and greenhouse gas emissions is positive, as we can see in figure no. 4, even though the coefficient indicates a very weak, almost non-existent correlation, it shows us that emissions are dependent on economic growth and an increase in environmental taxes will not significantly reduce greenhouse gas emissions, which can be observed in all EU countries.

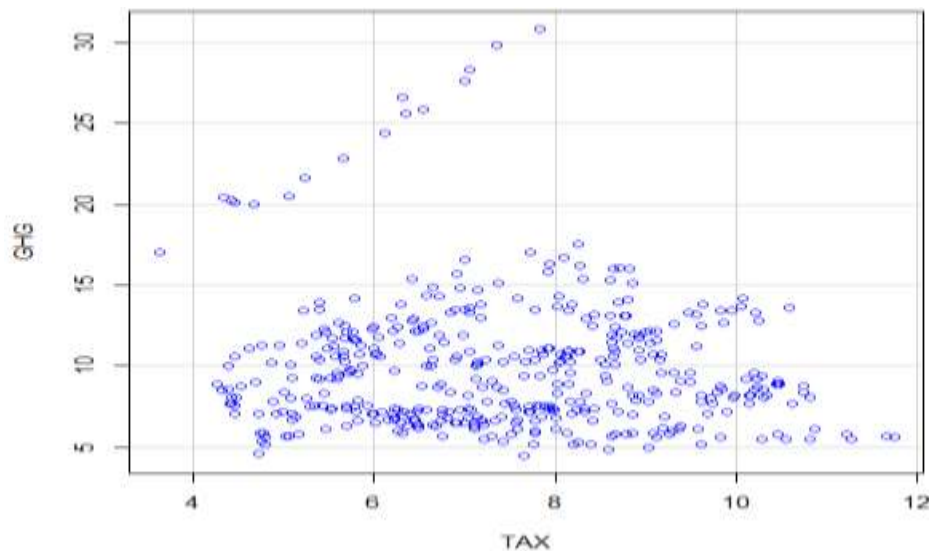


Figure no. 4. Correlation between GHG and TAX

Source: Own processing based on data from Eurostat (2022, b)

All coefficients are statistically representative at a confidence level of at least 95%, the value of the coefficient of determination R-squared is 97.9%, which tells us that there is little correlation/intensity between the variables (and expresses the fact that 97.9% of the variation in the dependent variable Y is determined by the variation in the variable x_i - from the estimated equation, the remaining 2.1% by other factors not captured), that the variables chosen explain the behaviour of the dependent variable, and the Durbin test statistic – Watson (Durbin-Watson stat) is 1.7 – showing that there is no autocorrelation of the errors. Furthermore, since the coefficient of determination R-squared is lower than the Durbin-Watson statistic, there is no spurious regression.

We used regression as a research method to determine and see the extent to which the dependent variables can reduce greenhouse gas emissions and the extent to which these variables can support the energy transition toward a renewable and sustainable economy.

GDP is a macroeconomic indicator that tells us the level of economic growth of a country at a given time, and it has a positive relationship with greenhouse gas emissions, because the more developed an economy is, the more resources are consumed, leading to an increase in industrialisation, transport, and energy consumption, which are sources of greenhouse gas emissions. However, the relationship between GDP per capita and GHG emissions is not linear, as countries can adopt more efficient and cleaner technologies and practices as they develop, reducing their GHG emissions and enabling sustainable development even as their GDP increases. This variable can support the energy transition if economically developed countries break this link through policies and investments in green energy, energy efficiency, and sustainable practices.

There is an inverse relationship between greenhouse gas emissions and energy productivity. The higher the energy productivity of an industry, the fewer greenhouse gases are emitted

per unit of energy produced. This relationship is illustrated by the carbon intensity indicator, which measures the amount of carbon dioxide (CO₂) emissions produced per unit of energy consumed, and the lower the carbon intensity, the more efficient the production and the fewer gas emissions are produced. There is a need to find technologies and practises that can increase energy productivity and reduce greenhouse gas emissions, such as finding alternative sources of renewable energy: Solar energy by using photovoltaic panels to convert sunlight into electricity; wind energy to generate electricity from the kinetic energy of the wind; hydroelectric energy by harnessing the energy of flowing water; geothermal energy by harnessing the heat of the earth; biomass energy that generates energy from organic materials; wave energy; tidal energy; the construction of energy storage systems; the construction of energy-efficient buildings; the use of electric or hybrid vehicles in both the private and public sectors, etc.

Increasing the share of renewable energy in the energy mix is an important step toward reducing greenhouse gas emissions and creating a sustainable energy future. The more renewable energy used, the lower the greenhouse gas emissions associated with energy production.

Environmental taxes are a policy tool that governments can use to reduce greenhouse gas emissions and incentivise environmentally friendly behaviour. When taxes are higher, the government encourages economic agents to adopt more environmentally friendly practices to avoid paying higher taxes. When environmental taxes are low, it means that the government does not focus on reducing GHG emissions or encouraging environmentally friendly behaviour, which leads to higher emissions because economic agents do not have incentives to adopt more environmentally friendly practices. However, the relationship between environmental taxation and GHG emissions is more complex and can take several forms: Carbon taxes, fuel taxes, and taxes on emissions from industrial processes. By putting a price on carbon and other forms of pollution, environmental taxes can encourage an economy to adopt cleaner technologies, reduce energy consumption, and switch to low-carbon alternatives. A study by the International Energy Agency found that a carbon tax of \$30 per ton of CO₂ could reduce global energy-related emissions by 6% by 2030 and provide governments with revenue to invest in clean energy technologies (European Court of Auditors, 2022).

Sustained growth in renewable energy investment will contribute significantly to achieving the European Green Deal's key objective of net neutrality in terms of greenhouse gas emissions by 2050 and can help reduce the impact of climate change. In addition, investment in renewable energy can create jobs and economic growth, contributing to the sustainable development of the EU. However, a much more comprehensive approach is needed, including other measures such as reducing energy consumption, increasing energy efficiency by promoting innovation and developing clean technologies, and raising awareness, informing, and educating economic actors in order to maintain a clean and healthy environment for both current and, in particular, future generations.

Conclusions

The transition to a green economy is no longer a future solution, but an emergency, and an emergency requires immediate and radical action, that is, action, not promises. Pollution is the consequence of promoting excessive, artificial, irrational and wasteful consumption,

both from the point of view of producers and consumers, so that more is not synonymous with better or quality, tastier is not synonymous with healthier, the state of comfort is not synonymous with well-being, consumerism is not synonymous with quality of life, the accumulation of goods is not synonymous with happiness, etc., and so today we are forced to reflect on the first forms of human organisation and ask ourselves the following question: How did they satisfy the needs of our great-grandfathers, from physiological to group needs? Were they more fulfilled, happier, healthier? Modern society has evolved in terms of how we have access to goods and their quality, but people are not happier, healthier, and more fulfilled, so the impact of economic growth acts as a boomerang on all living things. In this sense, the transition to a green economy is a necessity, and we must invest in green technologies, in projects and programs that create goods based on renewable, recyclable, and reusable resources, and maintain a clean, healthy, and friendly environment, in the local, regional and national contexts as well as the international context.

The econometric model we have built shows very clearly that a developed society will entail an ever-increasing consumption of resources and, of course, greenhouse gas emissions will also increase. Thus, GDP per capita has a direct impact on the increase in GHG emissions, as is also evident from the econometric analysis. A 1% increase in GDP per capita leads to an increase in GHG emissions of about 0.86 percentage points. Similar conclusions have been reached by other studies (Chiu and Chang, 2009), which show that a developing global economy leads to an increase in carbon dioxide emissions, even though more and more countries are focusing on renewable energy adoption. Khan, Khan and Binh (2020) also show that an increase in renewable energy consumption has a negative impact on carbon dioxide emissions, while financial development has an increasing impact on these emissions.

An important variable that can lead to a reduction in GHG emissions per capita is energy productivity. A 1% increase in energy resource productivity results in an estimated decrease in emissions of about 0.2 percentage points. Another variable that has a negative relationship with GHG emissions is the share of renewable energy in gross final energy consumption by sector. A 1% increase in the share of renewable energy in consumption results in a reduction in GHG emissions of about 0.06 percentage points, although this percentage is not high, it highlights the importance of renewable energy use for the natural environment. GHG emissions are a negative externality because the private costs and benefits are greater than the social costs and benefits, and one solution would be to internalise the externalities or pay taxes that discourage producers from emitting more GHG emissions, which would have devastating effects on the environment. According to the econometric model data, a one percentage point increase in the share of taxes in government revenues led to an increase in emissions of almost 0.09 percentage points, showing that an increase in environmental taxes does not significantly reduce GHG emissions, a situation observed in all EU countries.

The transition to alternative energy and sustainable development implies change, adaptation, and cooperation in finding effective solutions for all actors in economic and human life, in order to maintain a balance between production and consumption, between the economy and the natural environment, between economic growth and quality of life, in both national and international contexts.

The limitations of this study are that the analysis refers to a limited number of variables included in the SDGs and that the model could be extended to the level of every country in the European Union.

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