Climate Policy Development and Implementation from United Nations Sustainable Development Goals Perspective

Krzysztof Kluza (kkluza@sgh.waw.pl)
Warsaw School of Economics: Szkola Glowna Handlowa w Warszawie https://orcid.org/0000-0002-2792-8234
Magdalena Ziolo
University of Szczecin: Uniwersytet Szczecinski
Marta Postula
University of Warsaw: Uniwersytet Warszawski

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Abstract

Climate change is a challenge nowadays. Governments all over the world are debating how to mitigate environmental risk and how to address climate policies to achieve sustainable development goals (SDGs). This study aims to understand the interactions between climate policy development and different SDGs. The study analyses data from 2008 and 2018 for European Union Member States. Greenhouse gas emissions (GHG) were used as a dependent variable. The study tests the non-linear effects, which allow Environmental Kuznets curve phenomena to be identified and extends this line of research by checking the non-linearity and time-lagging of all explanatory variables. The research results show that it is possible to achieve climate policy goals not only directly, but also indirectly by facilitating the implementation of other SDG goals like *inter alia* SDG9 (innovation and infrastructure), SDG5 (gender equality), SDG11 (sustainable cities and communities) and SDG17 (environmental taxation). The impact of particular policies is also dependent on geographic-specific effects, analysed in this research with the use of factorial analysis.

1. Introduction

Sustainability risk or, in other words, the risk of non-financial factors (Environmental, Social, Governance (ESG) risk) is a type of risk that gains importance in the context of its impact on the business and the economy (Aziz et al. 2016). The definition of ESG risk is heterogeneous and work is currently underway on its unification (*inter alia* at the level of the European Banking Authority). Environmental risk is gaining importance, which is confirmed by the Global Risks Reports, showing that it is the top risk of the five risks with the greatest impact. The risk of climate change is one of the leading types of risk in this group (GRR, 2020). More and more often in studies and reports it is pointed out that the risk of non-financial factors affects financial performance (Deloitte, Sustainability Risk Management, 2019).

In the ESG risk group, environmental risk is a significant component, and within it, the risk of climate change. The risk of climate change is one of the five most impacting risks (GRR, 2020). There is no sector that is not affected by climate change and its consequences (Lawrence et al. 2020). Climate change determines the growing costs of running a business, but also the costs of public actions mitigating the impact of these changes (Kalkuhl and Wenz, 2020).

Hence, governments around the world are conducting an integrated debate on how to prevent climate change and its negative effects. This is done both on the international arena (including the United Nations Sustainable Development Goals in the field of climate) and at the level of the European Union (a number of strategic documents, including the European Green Deal, the EU's taxonomy regulation), or intergovernmental initiatives (e.g. climate summits). Individual states also undertake their own, internal efforts and actions aimed at protecting against the influence of climate risk, e.g. tax systems based on environmental taxes, the polluter pays principle, systems of subsidies and support for green transformation.

EU sustainability policies are also the answer to climate change. One of the key policies in this regard is climate policy and sustainable finance within the Capital Markets Union, and within sustainable finance, the leading role in the issue of climate change and the related risk is played by climate finance. Climate policy goals are in line with sustainable development goals (SDGs) dedicated to the environment and climate change, in particular SDG13. An important aspect here is also the question of financing climate policy development.

Among the SDGs, there is an SDG13 devoted to climate change, but it should be borne in mind that SDGs are integrated with each other, because their implementation should lead to the achievement of policy goals for sustainable development. Hence, it is not only the implementation and financing of SDG13 that have an impact on climate change. Climate indicators and actions, as a result of which environmental goals are achieved, are also found in other SDGs; this applies to both so-called economic and social goals. The question of how to finance and achieve individual goals in order to maximize their beneficial impact on the environment and counteract climate change remains an open question (Kluza et al. 2021).

There is a gap in the research on the relationship between climate policy and SDGs. In this context our study aims to understand interactions between the climate policy development and different SDGs, which is a novel and original approach and covers a research gap in the area. According to Bhandary et al. (2021) there are numerous conceptual models for how climate finance could work and what kinds of climate finance can be useful, but no empirical assessment has yet been conducted about how climate finance policies work in practice; see also Ziolo et al, 2019.

Lebel (2014) argues that the lack of evidence-based climate change adaptation practices results from relevant knowledge being inaccessible, unused, or missing. Most of the literature on climate change is written from a natural sciences perspective. Before 2010, only around 5% of the scientific papers published on climate change were written from a social science perspective. Further policy research could see important contributions to climate change policy development.

Sustainable Development Goals (SDGs) are the subject of a large number of studies (Singh et al. 2018, Flörke et al. 2019, Hutton et al. 2018, Zhang et al. 2016); however, only some of them focus on interactions between particular goals or the impact of one goal on others, but none of the studies deal with this problem in the context of climate policy development.

The aim of this article is to analyse and clarify the relationship between climate policy development and SDGs. In particular, the article raises the following research questions:

1. Which of the SDGs contributes to the achievement of climate policy development?
2. Whether and what kind of interactions may be observed among SDGs, and how they impact on the achievement of the goals of climate policy development?

The paper is organized as follows: the introduction is Section 1; in Section 2, the theoretical aspects related to SDGs are presented. Section 3 presents the methodological approach, data collection procedure, and description of the methods. Section 4 discusses the research results, and Section 5 is the conclusion.

2. Literature Review

A successful implementation of the sustainable development strategy of Agenda 2030 is a framework to meet the global sustainable development challenge to ensure human welfare, economic prosperity and environmental protection. To that end, all SDGs must act as a system of interconnected correlations, which together take the global social and economic system into a safe and fair functional space (Renaud et al. 2020; Pedercini et al. 2019). It would be unreasonable to expect that actions as part of one sustainable development goal alone will bring the desirable results with no support from the comprehensive process of social and economic intervention, which is why a synergy of their impact is necessary. Consequently, the achievement of sustainable development goals will greatly depend on whether synergies can be leveraged and trade-offs identified and resolved. The synergies observed show a broad compatibility of SDGs, where progress in one goal can contribute to the fulfilment of others (Kroll et al. 2019). This is why policies to support the inter-sectoral and inter-goal synergy relations will play a key role in making the sustainable development strategy operational (Nilsson et al. 2016; Reihaneh et al. 2022).

The natural environment is present in each and every of the Sustainable Development Goals. For example, the goals directly linked to the quality of the environment are SDG6 (clean water and sanitation), SDG13 (climate action), SDG14 (life below water) and SDG15 (land and biodiversity), while others are indirectly connected with the environment, e.g. SDG2 (zero hunger), SDG1 (no poverty) and SDG11 (sustainable cities and communities). Some researchers go even further, being of the opinion that environmental indicators are virtually inherent in all sustainable development goals, and, in particular, they argue that at least one such indicator exists for each of the goals (except for SDG10, which horizontally connects social, environmental and economic matters). Ninety-three indicators directly related to the environment have been created as part of sustainable development goals. Our research aims to demonstrate real synergies between the respective sustainable development goals and SDG13.10, representing climate policy goals. In practice, this would allow to attain environmental goals indirectly as a positive externality of successful implementation of other social, economic and development policies.

The existence of the system of correlations has been analysed for at least a dozen or so years, their results still being inconclusive and evolving with the societies' growing awareness of the behaviours defined by sustainable development goals (see for example Ziolo et al. 2020). A good example of such an approach would be the research conducted by Pradhan et al. (2017), which has demonstrated the existence of negative correlations with the same goal. Those researchers have also proved that such inverse correlations are observed mainly as part of SDG7 (affordable and clean energy), SDG8 (decent work and economic growth), SDG9 (industry, innovation and infrastructure) and SDG15 (life on land) for 25%-40% of data pairs. For example, the "percentage of population with access to electricity", SDG7 indicator, has increased in some countries as a result of the expansion of renewable energy sources (Wamukonya, 2003; Pradhan et al. 2017). This might not support the increase in the "share of renewable energy sources in total energy consumption", another SDG7 indicator.

There is also the issue of goals related to climate indicators and their impact on decisions taken by enterprises. Eiadat et al. (2008) argued there is a positive relation between the environmental innovation strategy and business performance. Moreover, Lee et al. (2015) claimed that R&D investment in the area of CO2 emission reduction has a positive impact on a company's performance.

In turn, research by De Neve and Sachs (2020) has revealed there are usually more synergies than trade-offs within and across sustainable development goals in most countries. Analyses by those researchers show that SDG3 (good health and well-being) is mainly connected with additional synergy benefits while SDG12 (responsible consumption and production) is significantly linked with the most problematic trade-offs. There are also studies demonstrating that most sustainable development goals are positively correlated to well-being, while the analysis by De Neve and Sachs shows quite a different scenario, where SDG12 (responsible consumption and production) and SDG13 (climate action) are negatively correlated in terms of subjective well-being (SWB) (O'Neill et al. 2018). However, the results of these analyses come as no surprise as the economic development measurement has long been based on the use of natural resources, causing the growth of human well-being to come, in most cases, at the expense of environmental sustainability (Krueger and Gibbs, 2007; Dietz et al. 2009).

Over the years, however, it has become increasingly clear that if we want to avoid an environmental breakdown, we must restrict the consumption of natural and material resources to the level consistent with the environmental limits (Meadows et al. 2004; PCC, 2018). This transition is captured by SDG12 and SDG13. This will entail an actual emission reduction and both quantitative and qualitative change in consumption and production patterns (Bengtsson et al. 2018). However, the analysis of correlations between these SDGs should be conducted taking account of the disposable household income indicator. As a matter of fact, an operating pattern can be observed in which high-income countries in particular must reduce their carbon footprint to enable consumption growth in countries undergoing economic development, where it is necessary to satisfy basic needs (Scherer, 2018). It is no easy task considering that a system driven by economic growth is dependent on continuously growing consumption and production to ensure employment and support sources of livelihood (Delanka-Pedige et al. 2021). Consequently, in the current structures, progress achieved in SDG12 and SDG13 may have serious social and economic implications and as such have a negative impact on the well-being especially of those most vulnerable (Bengtsson et al. 2018).

Nevertheless, environmental management does not necessarily entail a decline in well-being. Various studies have demonstrated the significance of environmental integrity to human well-being: for example, poor air quality has a negative impact on subjective well-being (Levinson, 2012; Hallegatte et al. 2018). People are willing to pay for noticeably cleaner air; there is evidence to suggest that contact with nature improves mental health (Repke et al. 2018). Much lesser social consequences of intensive environmental protection measures are recorded in countries where governments significantly support this action with dedicated tax and expenditure policies. A lot of studies can be found in the literature discussing the environmental impact of public expenditure, sometimes in relation to GDP. Taking 12 European countries in 1995–2008 as an example, López and Palacios (2014) proved that public expenditure had played a major role in limiting sulphur oxide and ozone emissions. No such effect, though, was recorded for nitrogen oxide. Meanwhile, Bostan et al. (2016) and Czyzewski et al. (2019) confirmed the correlation between the scale of public expenditure in EU-25 countries and the PM2 emission reduction, i.e. it was proved that an increase in expenditure causes PM2 to drop significantly. In other studies, Halkos and Paizanos (2017) examined the impact of government expenditure on GHG emissions in respective panels, reaching the conclusion that although greater public expenditure as a share of GDP favoured a reduction in sulphur and nitrogen oxide emissions, there was no such impact on carbon dioxide. Moreover, in low-income countries, the impact of government expenditure on emission reduction is strong, but in wealthier countries there can be even a positive correlation between growing expenditure and emissions. Generally speaking, the direct effect of public expenditure is more important and becomes stronger with GDP growth and an increase in the level of democratisation.

What can be generally observed in the results of various scientists' research is a low efficiency of tax receipts on environmental protection. This can be partly explained by the fact that their level is generally declining, while the emissions of some key pollutants are on the rise (e.g. CO_2 or NH_3), suggesting that these taxes are not consistently imposed. Moreover, pollution taxes represent merely a fraction of total environmental tax revenues, their distribution varying greatly between Member States. For example, pollution taxes imposed on farmers (applicable to NH_3 emissions, among others) were generally very low, except in a few Member States. This might suggest that the "polluter pays" principle does not yield the expected results (Postuła and Radecka-Moroz, 2020).

Hence, the challenge to political decision-makers is to solve the short-term trade-off by separating the improvement in human well-being from the consumption of natural resources and greenhouse gas emissions. One of the OECD reports (2019) attempts to meet this challenge by suggesting to adopt a well-being lens in climate change mitigation policies, placing humans at the centre of climate action (Roberts, 2020). Countries that achieve good results while ensuring high well-being indicate that there may be pathways out of poverty which do not frustrate environmental sustainability efforts. These countries represent a proportional mix of relatively large and small countries all over the world.

3. Methodology And Results

This article assesses the impact of implementation of different sustainable development goals on greenhouse gas emissions. Greenhouse gas emissions (GHG) were used as a dependent variable representing environmental degradation or a proxy for the implementation of environmental policies, based on the literature review (see e.g. Shahbaz et al. 2016b; Lapinskienė at al. 2017; Sterpu et al. 2018; Kluza et al. 2021). Namely, we used the greenhouse gas (CO_2 and N_2O, CH_4 in CO_2 equivalent) emissions in the kilogrammes (thousands) per capita indicator from the Eurostat database.

The analysis encompasses three groups of procedures:

1. panel data preparation and structuring of variables, including analysis of collinearity;
2. selection of the basic model specification through the panel data modelling, including a precedent testing of variable stationarity;
3. formulation of the final model specification with time lags and checking the marginal effects of variables, including geographic-specific effects with the use of factorial analysis.

The methodological aspects of all these stages are briefly described below. Due to the large number of analysed variables (over 70 indicators), the output for interim statistical procedures is not presented in the paper, but it is available on request.

Initially all the variables within respective SDGs were considered. All of the variables came from the Eurostat database for the period 2008–2018 to ensure a full integrity and comparability of the data. The data for EU 25 countries including the United Kingdom. Cyprus, Malta and Luxembourg were excluded due to the small size of their economies.

Firstly, the variables with missing observations for a whole year were excluded from the panel. This resulted in the elimination 15 variables due to data unavailability. Then, for the remaining variables full data completeness was assured, i.e. occasional missing observations were filled with proxy data, being a geometric mean of adjacent observations. This procedure encompassed less than 0.1% of all observations and allowed to obtain a balanced panel. This augmentation is important as with the relatively short time series any missing data would eliminate full year observations, which would affect the model's credibility.

Then, the remaining variables were transformed to relative indicators for better data comparability. This alteration affected 6 variables. The final step in data preparation was devoted to the elimination of collinearity between specific variables and the GHG variable. Variance inflation factors were used to detect collinearity through the iterative regression process. This eliminated the additional 8 variables.

The second group of procedures was devoted to the selection of the basic model specification. At the beginning the stationarity of data was checked. We employed the Levin-Lin-Chu test for panel ADF with time lag equal to 1 (Staszczyk, 2017). The undertaken procedure revealed that 6 variables were non-stationary of degree 1. Consequently, all variables were converted from their original values to their first differences to eliminate non-stationarity. Using first differences of variables still allows for relatively easy and straightforward interpretation of model coefficients.

The subsequent econometric modelling was carried out with the panel data regression functions. It is a prevailing econometric approach in this category of research, devoted to the issues of interdependence between socio-economic development, energy policy and environmental phenomena – see e.g. Tamazian et al. (2009), Aydin and Esen (2018), Ganda and Garidzirai (2020), Wang et al. (2020) and Sheraz et al. (2021a).

In our research, following Tamazian et al. (2009), we test the non-linear, i.e. U-shaped and N-shaped effects, which allow to identify the Environmental Kuznets curve phenomena (see e.g. Grossman and Krueger, 1995). We extend this line of research by checking the non-linearity of all explanatory variables. However, it is important to notice that, in fact, we do not have an unrestricted domain, as the analysed values for independent variables are located within specific ranges. Thus, the pure quadratic effects typically shall not emerge and, in practice,we check the existence of non-linear effects in the shape of (monotonic) convexity or concavity. The regression function, which is modelled initially, has a form, as follows:

$$d\_GHG_{it} = \alpha + \beta_k \cdot d\_C_{it} + \gamma_k \cdot (d\_C_{it})^2 + v_i + \varepsilon_{it} \qquad (1)$$

where:

d_GHG_{it}—the dependent variable (GHG), a first difference;

d_C_{it}—set of explanatory variables (*k* variables) consisting of individual indicators within the specific sustainable development goals for each country and year – first differences;

i—the cross-sectional dimension, representing individual countries analysed (from 1 to the *N*-th country); *I* Î {1, *N*};

t—the time dimension (annual data);

a—the intercept;

b—the structural parameters for respective explanatory variables in d_C_{it} set (1,..., *k)*;

g—the structural parameters for respective explanatory variables in $(d\_C_{it})^2$ set (1,..., *k)*;

v_i—error term representing time invariant unobserved characteristics;

e_{it}—random error term.

As the result of the second set of procedures, a specification of the basic model (Model 1) was obtained, which is presented in 1. The econometric modelling was carried out with a ‘from general to specific’ approach that was based on the achievement of significance of individual variables, minimizing the information criteria (Akaike’s & Schwarz’s) as well as ensuring favourable results of joint tests on named regressors and no autocorrelation of error terms. The calculations were carried out with the Gretl ver. 1.9.90 and STATA 16.1 software.

In the modelling, pooled OLS panel data specification and fixed effects specification for individual *i* was used. The random effects specification was not feasible due to insufficient degrees of freedom in these models. The carried-out tests (test of variance of residuals and Breusch-Pagan test) indicated that the model with the pooled OLS panel data procedure is more appropriate (see Table 1).

Table 1. Model 1 - Basic specification of relationship between various SDG indicators and GHG

Pooled OLS; 250 observations; cross-section units = 25; time series length = 10. Beck-Katz standard errors.

	Coefficient	*p-value*		*Coefficient*	*p-value*
constant	0.016495	0.54982			
d_g01_30	-0.0226046	0.01774**	sq_d_g01_30	0.00138614	0.20188
d_g01_40	0.0362523	0.00126***	sq_d_g01_40	6.50308e-05	0.98508
d_g01_50	0.01612	0.00031***	sq_d_g01_50	-0.00155444	0.08882*
d_g02_30	-0.00297161	0.72819	sq_d_g02_30	-0.000544024	0.81812
d_g02_60	0.00164644	0.87352	sq_d_g02_60	-0.00276634	0.38829
d_g03_10	0.179812	0.00049***	sq_d_g03_10	-0.0162003	0.87496
d_g03_40	-0.00263802	0.93024	sq_d_g03_40	-0.0787836	0.00577***
d_g03_60	-0.0248627	0.01949**	sq_d_g03_60	-0.00300823	0.44698
d_g04_20	0.0237099	0.00973***	sq_d_g04_20	-0.00105129	0.33289
d_g04_50	0.00313767	0.37568	sq_d_g04_50	0.000891451	0.09321*
d_g05_50B	0.00530973	0.00108***	sq_d_g05_50B	-0.000529673	<0.0001***
d_g7_10	2.05907	<0.0001***	sq_d_g7_10	1.09584	0.00038***
d_g7_11	-0.140544	0.50538	sq_d_g7_11	-2.89037	0.00043***
d_g07_30	-0.206166	0.00004***			
d_g07_40	0.0129116	0.39433***	sq_d_g07_40	0.0112593	0.04258**
d_g07_60	0.0223981	0.00401***	sq_d_g07_60	0.00087429	0.06052*
d_g08_10	0.0875365	0.00010***			
d_g8_11	0.00844453	0.10582	sq_d_g8_11	-0.000838885	0.08330*
d_g09_10	-0.178272	0.07014*	sq_d_g09_10	-0.802373	0.04151**
d_g09_20	0.00857809	0.68651	sq_d_g09_20	-0.0553057	0.00002***
d_g09_40	-0.00251464	0.00183***	sq_d_g09_40	1.62348e-05	0.35199
d_g09_60	0.0215902	0.00252***	sq_d_g09_60	0.000433594	0.54223
d_g10_20	0.0514145	0.02424**	sq_d_g10_20	0.0417354	0.02036**
d_g10_30	-0.0224765	0.00002***	sq_d_g10_30	0.00100829	0.57182
d_g11_10	-0.0007228	0.93580	sq_d_g11_10	0.00079118	0.09668*
d_g11_40	0.0403499	0.04485**	sq_d_g11_40	-0.00351301	0.63846
d_g13_20	0.0829038	<0.0001***	sq_d_g13_20	-0.00134677	<0.0001***
d_g16_10	-0.242666	0.0001***	sq_d_g16_10	-0.0623318	0.20362
d_g16_20	0.0105142	0.07562*	sq_d_g16_20	0.00138323	0.43948
d_g16_61	-0.00644073	0.00374***	sq_d_g16_61	6.68319e-06	0.97157
d_g16_63	0.00897778	0.00010***	sq_d_g16_63	-8.59247e-05	0.65472
d_g17_30	0.0276779	0.01865**	sq_d_g17_30	0.0015655	0.62613
d_g17_50	-0.0864178	0.00040***	sq_d_g17_50	-0.00408133	0.87250

prefix ‘d_’ denotes a first difference;

prefix ‘sq_’ denotes quadratic function;

R-squared	0.938317	Adjusted R-squared	0.916977
F(64,185)	43.97158	P-value(F)	2.40e-84
Log-likelihood	147.3140	Akaike criterion	-164.6280
Autocorrelation of resid.-rho1	-0.183380	Durbin-Watson stat.	2.105666

White’s test statistics: LM = 150.617; p = P(Chi2(97)>150.617) = 0.000400138.

Wald’s test statistics: Chi2(25) = 589.421; p = 1.94013e-108.

Test statistics of the normal distribution of residuals: Chi2(2) = 15.2413; p = 0.000490232.

Residuals variance: 3.98777/(250-89) = 0.0247687

Total significance of group mean inequalities: F(24,161) = 0.869224 with p = 0.643085.

Breusch-Pagan test: LM = 2.39429 with p = prob(chi2(1)>2.39429) = 0.121779.

Source: own calculations.

Model 1 allowed to unveil several significant relationships between SDG indicators and GHG, and their directions. It also demonstrated that GHG dependent variable can be largely explained by other SDG indicators as the adjusted R-squared ratio amounted to 91.7%, while controlling for non-collinearity.

The final model specification was formulated in the third set of procedures (Model 2), taking into consideration that some SDG variables may have an intertemporal influence on the dependent variable. The analysed function was transformed into the following form for Model 2:

$$d\_GHG_{it} = \alpha + \beta_k \cdot d\_C_{it} + \gamma_k \cdot (d\_C_{it})^2 + \lambda_k \cdot d\_C_{it-1} + \varphi_k \cdot (d\_C_{it-1})^2 + v_i + \varepsilon_{it} \quad (2)$$

where:

d_GHG_{it}—the dependent variable (GHG), a first difference;

d_C_{it-1}—set of explanatory variables (d_C_{it}), lagged by one time period – first differences;

l—the structural parameters for respective lagged explanatory variables in d_C_{it-1} set (1,..., *k)*;

j—the structural parameters for respective lagged explanatory variables in $(d\_C_{it-1})^2$ set (1,..., *k)*;

The description for other variables and parameters are the same as in Equation 1.

The results of modelling are presented in Table 2. Similarly to Model 1, the pooled OLS panel data specification was the most appropriate. Model 2, supplemented with lagged variables, is characterized by an increased number of statistically significant coefficients than in Model 1 and better fitness. Its adjusted R^2 ratio amounts to 94.5%. The results are supplemented with the beta coefficient (see Table 2), which reflects the impact of each SDG variable on GHG with standardized regression coefficients.

Table 2. Model 2 – Final model specification of relationship between various SDG indicators and GHG

Pooled OLS; 225 observations; cross-section units = 25; time series length = 9. Robust standard errors (robust HAC).

	Coefficient	*p-value*	*beta*		*Coefficient*	*p-value*	*beta*
constant	0.0214978	0.34007					
d_g01_30	0.0005368	0.93517	.0019524	sq_d_g01_30	0.00138857	0.02420**	.0277964
d_g01_30_1	-0.0079146	0.12511	-.026969				
d_g01_40	0.0427862	0.0001***	.1084634	sq_d_g01_40	-0.0019226	0.66687	-.0123167
d_g01_40_1	-0.0031148	0.75307	-.0082429				
d_g01_50	0.00968102	0.0039***	.0387373	sq_d_g01_50	-0.00131342	0.03558**	-.0301537
d_g01_50_1	0.0055966	0.14294	.0239727				
				sq_d_g02_30	-0.00588381	0.00011***	-.0512086
d_g02_30_1	0.00207171	0.70425	.0050005				
d_g02_60	0.00808001	0.25944	.014602	sq_d_g02_60	-0.0129188	0.00005***	-.049583
d_g02_60_1	-0.0020677	0.70533	-.0043846	sq_d_g02_60_1	0.00711953	0.00346***	-.049583
d_g03_10	0.212725	<0.001***	.1196816	sq_d_g03_10	-0.125533	0.05597*	-.0367531
d_g03_10_1	-0.0711299	0.04015**	-.0419137				
d_g03_40	0.103913	0.0019***	.0913165	sq_d_g03_40	0.0527694	0.05127*	.0675324
d_g03_40_1	-0.158921	<0.001***	-.1511092	sq_d_g03_40_1	-0.0976825	0.00239***	-.1622791
d_g03_60	-0.0334946	0.0004***	-.0769306	sq_d_g03_60	-0.00365228	0.20097	-.0252522
d_g03_60_1	0.0165255	0.03852**	.0402346	sq_d_g03_60_1	0.00804934	0.00102***	.059166
d_g04_20	0.0133582	0.03534**	.0438812	sq_d_g04_20	-0.000842022	0.20313	-.020595
d_g04_20_1	-0.003585	0.48732	-.0113075				
d_g04_50	-0.0008469	0.73115	-.0057281	sq_d_g04_50	0.000851912	0.06073*	.0330972
d_g04_50_1	0.0121304	<0.001***	.0940137	sq_d_g04_50_1	0.0014407	0.00004***	.0795058
d_g05_50B	0.0016739	0.11843	.0235079	sq_d_g05_50B	-0.000488471	<0.0001***	-.1232035
d_g05_50B_1	-0.0037041	0.0019***	-.0528348	sq_d_g05_50B_1	-0.000148788	0.03265**	-.0377075
d_g7_10	1.87457	<0.001***	.5739955	sq_d_g7_10	0.939905	0.06065*	.0947399
d_g7_10_1	0.341869	0.04576**	.1154462	sq_d_g7_10_1	0.706619	0.01049**	.0787687
d_g7_11	-0.0229329	0.92061	-.0042532	sq_d_g7_11	-2.16599	0.00773***	-.0789985
d_g7_11_1	-0.248706	0.27976	-.0535374	sq_d_g7_11_1	-1.08258	0.07508*	-.0485148
d_g07_30	-0.220636	<0.001***	-.1784729				
d_g07_30_1	0.193596	<0.001***	.1587777				
d_g07_40	-0.0109823	0.35506	-.0209629	sq_d_g07_40	0.019314	0.00014***	.0821092
d_g07_40_1	-0.0204672	0.02131**	-.0445095				
d_g07_60	0.014755	0.0033***	.0680599	sq_d_g07_60	0.000395612	0.26861	.0234306
d_g07_60_1	-0.0074189	0.17997	-.0349169	sq_d_g07_60_1	-0.00156499	0.00010***	-.0930124
d_g08_10	0.0716126	0.0015***	.1241164				

d_g08_10_1	0.0244871	0.13149	.049889				
d_g8_11	0.0168965	0.01413**	.0561947	sq_d_g8_11	-0.00772239	<0.0001***	-.1600936
d_g8_11_1	0.0137362	0.0027***	.0598567				
d_g09_10	-0.122425	0.04431**	-.0295195				
d_g09_10_1	0.099181	0.26514	.0242854	sq_d_g09_10_1	-0.801495	0.00159***	-.0662743
				sq_d_g09_20	-0.0113304	0.25777***	-.0162824
				sq_d_g09_20_1	0.0208791	0.00153***	.0646229
d_g09_40	-0.0014259	0.01240**	-.0428871				
d_g09_40_1	0.00143298	0.01201**	.0458976				
d_g09_60	0.011069	0.0008***	.0481098	sq_d_g09_60	0.00174352	0.00007***	.0655903
d_g09_60_1	-0.0092516	0.0099***	-.042225				
d_g10_20	0.0390113	0.02966**	.0404229				
d_g10_20_1	-0.0580513	0.03940**	-.0681425				
d_g10_30	-0.0225029	0.0002***	-.0947828	sq_d_g10_30	0.00303056	0.04433**	.0505597
d_g10_30_1	0.00132111	0.76785	.0053254				
d_g11_10	-0.005789	0.05132*	-.0402902				
d_g11_10_1	0.00319506	0.39883	.0204625				
d_g11_40	0.0167087	0.29541	.0235965	sq_d_g11_40	-0.00575737	0.66552	-.0113789
d_g11_40_1	-0.0344304	0.03791**	-.0588767	sq_d_g11_40_1	-0.0176838	0.00212***	-.0722559
d_g13_20	0.0883594	<0.001***	.6953579	sq_d_g13_20	-0.000979757	0.00016***	-.13907
d_g13_20_1	0.00111988	0.77506	.0086292	sq_d_g13_20_1	0.000485864	0.01615**	.0678886
d_g16_10	-0.208839	0.0000***	-.1232576	sq_d_g16_10	0.0326988	0.51625	.0200664
d_g16_10_1	-0.1764	0.0051***	-.1154413	sq_d_g16_10_1	-0.170818	0.00049***	-.1256248
d_g16_20	0.010977	0.0005***	.0377855	sq_d_g16_20	-0.00282132	0.05567*	-.0317066
d_g16_20_1	0.0144532	0.0085***	.0557601				
d_g16_61	-0.0058344	0.0049***	-.0703388	sq_d_g16_61	0.0000412	0.78585	.0045523
d_g16_61_1	0.0019702	0.28858	.0238866				
d_g16_63	0.00444217	0.01276**	.0498204	sq_d_g16_63	-0.0000419	0.79648	-.0037437
d_g16_63_1	-0.000348	0.85283	-.0039468				
d_g17_30	0.00321946	0.79928	.0051332	sq_d_g17_30	0.0186392	0.00223***	.0540069
d_g17_30_1	-0.0286345	0.0013***	-.0600336				
d_g17_50	-0.044905	0.009***	-.0355851	sq_d_g17_50	0.0589688	0.00543***	.0360899
d_g17_50_1	-0.0295681	0.13733	-.0265848				

prefix ‘d_’ denotes a first difference;

prefix ‘sq_’ denotes a quadratic function;

suffix ‘_1’ denotes a lagged variable (t-1).

R-squared	0.970136	Adjusted R-squared	0.944714
F(103,121)	38.16193	P-value(F)	1.55e-61
Log-likelihood	238.8089	Akaike criterion	-269.6178
Autocorrelation of resid.-rho1	-0.037202	Durbin-Watson stat.	1.817173

White’s test statistics: LM = 165.368; p = P(Chi2(169)>165.368) = 0.564593.

Wald’s test statistics: Chi2(25) = 59.032; p = 0.000141953.

Test statistics of the normal distribution of residuals: Chi2(2) = 1.47802; p = 0.477586.

Residuals variance: 1.36765/(225-128) = 0.0140995

Total significance of group mean inequalities: F(24,97) = 0.61844 with p = 0.910823.

Breusch-Pagan test: LM = 3.18764 with p = prob(chi2(1)>3.18764) = 0.0741969

Source: own calculations.

Since the mathematical formulas describing behaviour of individual variables are relatively complex, a helpful approach is to use graphical analysis for understanding their joint influence on the GHG variable. The marginal effects of selected variables, i.e. their isolated impact on the GHG variable, are depicted in Figure 1. The charts are constructed for the typical variation ranges of particular SDG indicators, in order to illustrate their most probable effect on the dependent variable. The charts show the variables with the largest beta as well as the variables, on which we focus in our analysis from the perspective of the implementation of socio-economic goals. The obtained results are analysed in the discussion section in a subsequent part of this article.

The variables SDG7.10 and SDG13.20 play the largest role in explaining the dependent variable according to the beta metric. Their behaviour, predicted by Model 2 (see Figure 1, chart A & B), is fully in line with theoretical expectations. This additionally validates the correctness of the obtained econometric results.

As the literature shows, the link between environmental indicators and socio-economic policies is often country-specific – see e.g. Bluszcz and Manowska (2020), Sheraz et al. (2021b). Thus, we tested a possible heterogeneous impact of independent variables from the geographic dimension. The countries were grouped into three distinctive categories—Western and Northern Europe (WNE: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Netherlands, Sweden, United Kingdom), Mediterranean and Southern Europe (MSE: Greece, Italy, Portugal, Spain) and Central and Eastern Europe (CEE: Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia). The variable describing the geographic characteristic is referred to as *Cluster*.

This group of procedures in the modelling is based on the design of the experiment concept. Their aim is to identify how possible interactions between *Cluster* andselected SDG_i variables affect the behaviour of the *GHG* dependent variable. The methodology of this factorial analysis is widely described by Oehlert, 2010. In general, the following regression problem is solved (Equation 3 depicts a 2-way full factorial model with quadratic main effects and non-lagged variables):

$$y = \eta_0 + \eta_1 x_1 + \eta_2 x_2 + \ldots + \eta_k x_k + \eta_{11} x^2{}_1 + \eta_{22} x^2{}_2 + \ldots + \eta_{kk} x^2{}_k + \eta_{12} x_1 x_2 + \ldots + \eta_{k-1,k} x_{k-1} x_k + \epsilon \quad (3)$$

where:

y—experiment yield; in our case the *GHG* variable;

x_k—independent variables, in our case sustainable development goals indicators(d_C_{it}) and *Cluster* variables;

h_k—coefficients for independent variables;

$x_{k-1}x_k$—interactions between *k*-1 and *k*-th variables;

$h_{k-1,k}$—coefficients representing two factor interaction effects.

In this study, we limit ourselves to an analysis of only 2-way interactions of the given SDG indicator and the categorical *Cluster* variable. We isolate these interaction effects in such a way that we check each interaction separately instead of introducing them simultaneously in one joint equation. It means that several independent regressions are carried out to grasp the impact of geographical categories on a specific SDG indicator. The formulation of the relationship being modelled is presented in Equation 4.

$$d\_GHG_{it} = \alpha + \beta_k \cdot d\_C_{it} + \gamma_k \cdot (d\_C_{it})^2 + \lambda_k \cdot d\_C_{it-1} + \varphi_k \cdot (d\_C_{it-1})^2 + \eta_1 \cdot Cluster \cdot d\_\check{C}_{it} + \eta_2 \cdot Cluster \cdot (d\_\check{C}_{it})^2 + \eta_3 \cdot Cluster \cdot d\_\check{C}_{it-1} + \eta_4 \cdot Cluster \cdot (d\_\check{C}_{it-1})^2 + \varepsilon_{it} \quad (4)$$

where:

$d\_\check{C}_{it}$ and $d\_\check{C}_{it-1}$—a selected independent variable (one per each regression) from the set of all d_C_{it} variables, for which the factorial effects with the *Cluster* variableare examined;

Cluster—thecategorical variable representing ageographic area to which an individual country belongs to; it is comprised of three categories (WNE, MSE, CEE);

h_l—the structural parameters for a respective explanatory variable $d\_\check{C}_{it}$ and/or $d\_\check{C}_{it-1}$; *l* = (1,2,3,4);

The description for other variables and parameters are the same as in Equation 1.

In this article, the analysis of geographical differentiation of a given variable impact on GHG was conducted for a small group of variables selected by the authors to deepen their view on the specific phenomena. Namely, it included following SDG indicators: 5.50B, 7.40, 8.10, 8.11, 9.10, 17.50. The full results of these models are not presented in this article due to their large size. The variables' behaviour, illustrated by their marginal effects, is depicted in Figure 2. This should be treated as some supplementary evidence – indicating some promising observations but still at the early stage of research, specifically due to the relatively short time horizon of such an analysis. In short, two clusters delivered some statistically significant estimates. Namely, the separation of WNE and CEE cluster proved to be moderately significant for the following SDG indicators: 8.10, 8.11, 9.10, 17.50 (only WNE), 5.50B (only CEE).

4. Discussion

Identification and appropriate analysis of the links between the natural environment, economy and society are essential to making effective systemic decisions aimed at building sustainable solutions. Accurate interpretation and valuation of the natural environment's contribution to human functioning in various dimensions is one of the most important objectives carried out in the context of sustainable development policy. Our research on the impact of GDP per capita on greenhouse gas emissions has shown that the increase in the wealth of society causes an increase in air pollution. These results are consistent with studies that confirm that the relationship between CO_2 emissions and economic growth is negative (Azomahou et al. 2006; Caporale at al. 2021, Dogan and Aslan, 2017), or that it is initially positive but then turns negative (Riti et al. 2017; Shahbaz et al. 2016a), although some papers report instead a positive relationship (Chaabouni et al. 2016; Nasir and Rehman, 2011; Saidi and Mbarek, 2016). However, from the perspective of sustainable development, it is important to investigate whether the pursued economic policy is continuous, intelligent and sustainable growth influencing the implementation of a climate policy, measured by the reduction of greenhouse gas emissions, and not only growth measured by the GDP-based indicators. For this purpose, as part of the conducted study, it was decided to analyse the environmental impact of other economic factors such as the following: gross domestic expenditure on R&D; patent applications to the European Patent Office, investment share in GDP and share of environmental taxes in total tax revenues.

In the first step, it was decided to analyse the impact of the investment share in GDP level on greenhouse gas emissions, assuming that new investments should create pro-ecological behaviour, e.g. energy-saving, and it is important to note here the inverse relationship between these variables. However, the results turned out to be different, i.e. the increase in the share of investments in GDP does not significantly affect a reduction of greenhouse gas emissions. Such results may arise from the fact that new investments generate higher economic growth, which in turn requires additional energy, thus leading to increased greenhouse gas emissions. It is noted in the literature that investments are related to the dynamic development of human populations, cities and unlimited satisfaction of ever new human needs, and above all, that these processes impact the quality of the environment. Therefore, it is important to increase the share of pro-ecological investments in the pool of all investments that are being implemented.

The results obtained during the research confirmed that expenditure on research and development in European Union states effectively reduces greenhouse gas emissions. The growing share of R&D spending results in the development of low-carbon technologies and supports responsible climate policy in the medium-term. In the literature, many authors, such as Bernauer et al. (2006), Rehfeld et al. (2007) and Horbach (2008) came to similar conclusions, i.e. that R&D positively affects technological capabilities in environmental protection technology at the company level. On the other hand, Cuerva et al. (2014) show that R&D stimulates green innovation to a lesser extent than conventional innovation. Further, in their article, Chengshi and Zhenyi (2021) showed that technological innovations significantly influence environmental policies, and are the basis for formulating adaptive environmental policies as well as the promotion of sustainable environmental development. Results indicating no influence of patent applications to the European Patent Office on climate policy as measured by the greenhouse gas reduction index came as a certain surprise. Such results may probably be due to the fact that the patent itself is one of the elements that, without spending on its development and implementation as part of R&D, is only a tool that must be used to be able to observe the results in improving the environment. The literature devoted to the analysis of the changes taking place in the global economy in the face of constant technological progress, counteracting climate change, dwindling resources and the pursuit of a low-emission economy, emphasizes the growing importance of eco-innovation (Guo et al. 2020; Urbaniec et al. 2021; Carrota and Sticks, 2021) and not the patents themselves, which are considered to be only one element of a larger whole. Therefore, any actions of authorities within the framework of expenditure or tax policy (tax breaks) supporting R&D expenditure, in particular eco-innovation, which favour sustainable development, are in line with the results we have obtained.

The tax system can be an effective tool for conducting climate policy, not only in the case of supporting R&D spending. In recent years, taxes for environmental protection, which have experienced a renaissance at the European Commission level, can also be an effective way to reduce greenhouse gas emissions, depending, however, on their scope and broader economic context. The results obtained from our research in this area condition the effectiveness of the increasing share of environmental taxes in total taxes, *inter alia*, on the wealth of countries and the general level of taxes in relation to GDP, i.e. environmental taxes are a more effective tool in reducing emissions of greenhouse gases in wealthy countries. Since they constitute an additional burden for entrepreneurs, environmental taxes in underdeveloped or developing countries may result in the limitation of development activities, e.g. R&D expenditure, or force other savings that may adversely translate into the broadly understood state of the environment. In such cases, it is important to adapt the introduced solutions to the national conditions, because they may achieve the opposite environmental effect to the one assumed. In the literature, many scientists believe that levying an environmental tax is beneficial for the environment in terms of reducing pollution and carbon dioxide emissions. Liu et al. (2018) show that an ecological tax may not only favour the effects of pollution control, but also reduce the losses to the natural environment. Piciu and Tric (2012) prove that an ecological tax can be returned to the polluters, i.e. the ecological tax can, under certain conditions, reduce pollution and protect the environment. Tamura et al. (1996) believe that an ecological tax is effective for total control of carbon dioxide emissions only if a sufficiently high-elimination and low-cost technology is developed. Niu et al. (2018) and Fan et al. (2019) state that environmental tax shocks can lead to a reduction in carbon dioxide emissions.

Among the factors affecting GHG emissions, an important role, which is emphasized in the literature (Karimi et al. 2021), is played by variables from SDG7 (Ensure access to affordable, reliable, sustainable and modern energy). In particular, a key role here is played by three variables – energy productivity, primary energy consumption and share of renewable energy in gross final energy consumption. The choice of these variables is consistent with the actions of the European Union aimed at achieving climate neutrality by 2050. The decarbonisation processes and activities consisting in replacing traditional energy sources based on fossil fuels with renewable sources are key to achieving this goal. This is one of the assumptions of the European Green Deal. The research results confirm the positive relationship between GHG emissions and the growing share of renewable energy sources in gross final energy consumption. The research results show that the share of renewable energy in gross final energy consumption contributes to a reduction of greenhouse gas emissions. The higher the share, the more the emission level decreases. Other authors whose research results are consistent with those obtained in the study have also reached similar conclusions. An example of such research is the analysis conducted by Yamaka et al. (2021), who analysed the economic and energy impacts on greenhouse gas emissions in China and the USA. They declared that there is a strong relationship between renewable energy production and sustainable development in both countries. Karimi et al. (2021) analysed the relationship between economic growth, consumption of renewable energies and CO2 emissions in Iran between 1975 and 2017. They assume that renewable energies, CO2 emissions and economic growth are related in the short term. They pointed out that using renewable energy as a solution is still being hampered by rising investment costs in new technologies. Khan et al. (2020) concluded that renewable energy sources are reusable, which can reduce CO2 emissions as well as ensure the sustainable economic development of Pakistan.

Akdag and Yildirim (2020) confirm that there is a causal link between energy efficiency and greenhouse gas emissions in many European countries. They used datasets from 29 European countries between 1995 and 2016 and the result suggests that there is a long-term inverse relationship between energy efficiency and GHG emissions. Amponsah et al. (2014) in their study, taking into account renewable energy sources, waste treatment and dedicated biomass technologies, potentially high greenhouse gas emissions were identified based on the raw material, selected limits and the inputs required for their production. The study confirms additional impacts of renewable electricity and heating technologies, shows the effectiveness of life cycle analysis as a tool for evaluating the environmental impact of renewable energy sources and declares potential for future improvements. According to the study conducted by Gielen et al. (2019), renewable energies and energy efficiency in combination with the electrification of end uses make up 94% of the emission reductions.

Owusu et al. (2016) revealed opportunities related to renewable energy sources which consists of the following: energy security, access to energy, social and economic development, and mitigating climate change and reducing environmental and health impacts. According to their research, there are challenges that usually hamper the sustainable development of renewable energy sources and their ability to limit climate change. These challenges are market failure, lack of information, access to raw materials for the future use of renewable resources and, above all, human way of using energy inefficiently. Another factors with the positive impact on the reduction of GHG emissions are primary energy consumption and energy productivity. The authors such as Li et al. (2021), Salari et al. (2021) or Shaouhui and Tian (2020) pay attention to similar dependencies. Li et al. (2021) found that the amount of CO_2 emissions in different countries was closely related to the amount and type of energy consumed by them. Their research results highlight the importance of improving energy efficiency and adjusting the energy structure to decrease energy consumption and ensure sustainable development. According to Salari et al. (2021) research carried out for USA confirmed that total non-renewable, industrial and residential energy consumption has a positive impact on CO_2 emissions, while renewable energy consumption has a negative relationship with CO_2 emissions. Shaouhui and Tian (2020) found that there is a mutual relationship between energy consumption and CO_2 emissions. Energy consumption and carbon dioxide emissions are interrelated, which has a negative spatial impact on carbon dioxide emissions in the surrounding provinces and cities.

GHG emissions are also influenced by social aspects, e.g. poverty. In countries with a high proportion of the population suffering from poverty, environmental degradation is higher. Countries with high poverty rates experience high levels of energy poverty and environmental degradation at the same time. Awad and Warsame (2022) analysed the poverty-environment nexus in developing countries and came to the conclusion that while the bidirectional causality relationship between poverty and ecological footprint is discovered for the global panel and Africa, no causality is detected for the developing countries in Asia, Latin America, and Caribbean.

According to Khan (2019), poor people live in an unsustainable way and impact on environmental degradation based on natural resources (for example deforestation). The other problem is lack of fuel-efficient/green vehicles and green practices in poor societies, which results in greater GHG emissions. The research results presented in this paper fit into the discussion and the published research results (especially Khan, 2019). The analysis of SDGs leads to the conclusion that poverty has an impact on environmental degradation, resulting in excessive exploitation of natural resources and the use of heat sources negatively affecting the environment. The study confirms this relationship based on the analysis of SDG7 (Population unable to keep home adequately warm).

Women are strongly affected by climate risk and are therefore more concerned about climate change (Murray, 2020). In this context, the possibility of women influencing decision-making processes and influencing the shaping of climate policy becomes more important. This article examines this issue through the SDG5 analysis (women participation in national governments). The research results are in line with the results published by Mavisakalyan and Tarverdi (2018), who assume the representation of females in parliament results in lower carbon dioxide emissions.

5. Conclusion

The importance of climate policy is growing in the context of the impact of environmental risk on business, society and the economy. The aim of the paper is to analyse the interactions between climate policy development and various SDGs. One of the limitations of the study is the data set. Eurostat currently uses 100 different indicators to monitor progress in the implementation of the 2030 Agenda; some of them are updated less than once a year (12 indicators) and in the case of a further 23, information on them is only available in an aggregated form on a European basis level.

The general results of the study confirm that there are statistically significant interactions between SDG 13.10 (GHG) and several SDGs. Specific variables from the SDG7, SDG13 goals have the greatest normalized influence on the dependent variable. The study argues that GHG is linked to the environmental, social and economic pillar of sustainable development represented by SDG1, SDG3, SDG4, SDG5, SDG7, SDG8, SDG11, SDG 13, SDG16, SDG17.

The article indicates that interactions between particular SDGs support the implementation of climate policy development. The implementation of SDG7 and SDG13 has the strongest impact on climate policy development because both SDG7 and SDG13 relate to energy consumption, which has an impact on the amount of GHG emissions. SDG7 additionally refers to renewable energy sources, the share of which is systematically growing in EU countries as a result of public policies supporting the energy transformation, e.g. through systems of discounts and subsidies for renewable energy sources.

SDG7, SDG9, SDG17 support climate policy development because they influence the behaviour of market entities that contribute to the reduction of GHG emissions. Environmental taxes included in SDG17 support the reduction of GHGs by influencing the decisions of taxpayers (dirty business ceases to pay off as "polluters pay"). Environmental taxes can be an efficient way of reducing greenhouse gas emissions, depending on their scope and the general policy context. R&D spending effectively reduces greenhouse gas emissions. R&D expenditure included in SDG9 through support for green innovations is another example of a positive impact on climate policy development through the implementation of SDG9. Technological solutions and industrial innovation can help reduce greenhouse gas emissions. The patent application variable requires further investigation.

The research results show that social factors also influence the amount of GHG emissions, in addition to economic ones. In particular, the level of society's wealth and living conditions have an impact on consumption patterns which, for countries with high levels of poverty, lead to unsustainable consumption increasing environmental degradation. Poor living conditions result in unsustainable consumption and an increase in environmental degradation. Also, the position of women and their influence on decisions, in other words, gender issues, are important. Women will feel the effects of climate change more strongly than men, hence they are more sensitive to these changes and make more environmentally friendly decisions. The participation of women in parliament is therefore important for GHG emissions and the implementation of climate policy.

The study confirms that the energy efficiency which may be achieved by SDGs brings a number of environmental benefits. In particular, it reduces greenhouse gas emissions, both direct emissions from combustion or the consumption of fossil fuels and indirect emissions from electricity generation. Future work will focus on two fields: cluster analysis with respect to country affluence, location etc. and multiway factorial analysis of variables in order to extract indirect effects/impacts between particular SDGs.

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Competing Interests

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The authors have no conflicts of interest to declare.

Research involving Human Participants and/or Animals:

Not-applicable.

Authors Contributions

Conceptualization: MZ, KK, MP; Methodology: KK; Formal analysis and investigation: KK; Writing - original draft preparation: MZ, MP, KK; Writing - review and editing: KK, MZ, MP; Funding acquisition: MZ.

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Consent to Participate

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References

1. Akdag S, Yıldırım H (2020) Toward a sustainable mitigation approach of energy efficiency to greenhouse gas emissions in the European countries. Heliyon 6(3) DOI 10.1016/j.heliyon.2020.e03396.
2. Amponsah NY, Troldborg M, Kington B, Aalders I, Hough RL (2014) Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations. Renewable and Sustainable Energy Reviews 39: 461-475DOI 10.1016/j.rser.2014.07.087.
3. Azomahou T, Laisney F, Van PN (2006) Economic development and CO2 emissions: A nonparametric panel approach. Journal of Public Economics 90: 1347–1363.
4. Awad A, Hersi WM (2022) The poverty-environment nexus in developing countries: Evidence from heterogeneous panel causality methods, robust to cross-sectional dependence. Journal of Cleaner Production 331 DOI 10.1016/j.jclepro.2021.129839.
5. Aziz NAA, Manab NA, Othman SN (2016) Critical Success Factors of Sustainability Risk Management (SRM) Practices in Malaysian Environmentally Sensitive Industries. Procedia - Social and Behavioral Sciences 219: 4-11 DOI 10.1016/j.sbspro.2016.04.025.
6. Aydin C, Esen Ö (2018) Reducing CO2 emissions in the EU member states: Do environmental taxes work?. Journal of Environmental Planning and Management 61(13): 2396-2420.
7. Bengtsson M, Alfredsson E, Cohen M, Lorek S, Schroeder P (2018) Transforming systems of consumption and production for achieving the sustainable development goals: moving beyond efficiency. Sustain. Sci. 13:1533-1547.
8. Bernauer T, Engels S, Kammerer D, Seijas J (2006) Explaining green innovation: Ten years after porter's win-win proposition: How to study the effects of regulation on corporate environmental innovation?. Working Paper 17 ETH, Zurich and University of Zurich.
9. Bluszcz A, Manowska A (2020) Differentiation of the level of sustainable development of energy markets in the European Union countries. Energies 13(18):4882.
10. Caporale GM, Claudio-Quiroga G, Gil-Alana LA (2021) Analysing the relationship between CO2 emissions and GDP in China: a fractional integration and cointegration approach. J Innov Entrep 10/(32) DOI 10.1186/s13731-021-00173-5.
11. Chaabouni S, Zghidi N, Mbarek MB (2016) On the causal dynamics between CO2 emissions, health expenditures and economic growth. Sustainable Cities and Society 22:184–219.
12. Chengshi T, Zhenyi H (2021) Can stringent environmental policy encourage technological innovation in industrial enterprises?. Science Research Management42(10): 166-173.
13. Costa J (2021) Carrots or Sticks. Which Policies Matter the Most in Sustainable Resource Management?. Resources 10:12.
14. Czyzewski B, Matuszczak A, Kryszak Ł, Czyzewski A (2019) Effectiveness of the EU Environmental Policy in Struggling with Fine Particulate Matter (PM 2.5): How Agriculture Makes a Difference?. Sustainability 11(18): 1-17.
15. De Neve JE, Sachs JD (2020) The SDGs and human well-being: a global analysis of synergies, trade-offs, and regional differences. Sci Rep 10: 15113 DOI 10.1038/s41598-020-71916-9.

16. Delanka-Pedige HMK, Munasinghe-Arachchige SP, Abeysiriwardana-Arachchige ISA, Nirmalakhandan N (2021) Wastewater infrastructure for sustainable cities: assessment based on UN sustainable development goals (SDGs). International Journal of Sustainable Development & World Ecology 28/3: 203-209.
17. Deloitte (2019), Sustainability Risk Management. Powering performance for responsible growth, Deloitte Southeast Asia Ltd.
18. Dietz T, Rosa EA, York R (2009) Environmentally efficient well-being: rethinking sustainability as the relationship between human well-being and environmental impacts. Hum. Ecol. Rev. 16: 114–123.
19. Eiadat Y, Kelly A, Roche F, Eyadat H (2008) Green and competitive? An empirical test of the mediating role of environmental innovation strategy. J. World Bus. 43: 131–145.
20. Fan X, Li X, Yin J (2019) Impact of environmental tax on green development: A nonlinear dynamical system analysis. PLOS ONE 14(9): e0221264 DOI 10.1371/journal.pone.0221264
21. Flörke M, Bärlund I, van Vliet MT, Bouwman AF, Wada Y (2019) Analysing trade-offs between SDGs related to water quality using salinity as a marker. Curr. Opin. Environ. Sustain. 36: 96–104.
22. GRR (2020). Global Risks Report, https://www.weforum.org/reports/the-global-risks-report-2020 (accessed: 27.09.2021).
23. Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R (2019) The role of renewable energy in the global energy transformation. Energy Strategy Reviews 24: 38-50 DOI 10.1016/j.esr.2019.01.006.
24. Grossman GM, Krueger AB (1995) Economic growth and the environment. Q. J. Econ. 11: 353–377 DOI 10.2307/2118443.
25. Guo J, Chen M, Sun X, Wang Z, Xue J (2020) Leveraging industrial-technological innovation to achieve sustainable development: A systems thinking perspective. PLoS ONE 15(12).
26. Halkos GE, Paizanos, EA (2017) The channels of the effect of government expenditure on the environment: Evidence using dynamic panel data. J. Environ. Plan. Manag. 60:135–157.
27. Hallegatte S, Fay M, Barbier E (2018) Poverty and climate change: Introduction. Environment and Development Economics 23(3): 217-233 DOI 10.1017/S1355770X18000141.
28. Horbach J (2008) Determinants of environmental innovation: New evidence from German panel data sources. Research Policy 37(1): 163–173.
29. Hutton CW, Nicholls RJ, Lázár AN, Chapman A, Schaafsma M, Salehin M (2018) Potential Trade-Offs between the Sustainable Development Goals in Coastal Bangladesh. Sustainability 10:1108.
30. Kalkuhl M, Wenz L (2020) The impact of climate conditions on economic production. Evidence from a global panel of regions, Journal of Environmental Economics and Management 103/102360, DOI 10.1016/j.jeem.2020.102360.
31. Karimi MS, Ahmad S, Karamelikli H, Dinç DT, Khan YA, Sabzehei MT, et al. (2021) Dynamic linkages between renewable energy, carbon emissions and economic growth through nonlinear ARDL approach: Evidence from Iran. PLoS ONE 16(7): e0253464.
32. Khan MK, Khan MI, Rehan M (2020) The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financ Innov 6/(1) DOI 10.1186/s40854-019-0162-0
33. Khan SAR (2019) The nexus between carbon emissions, poverty, economic growth, and logistics operations-empirical evidence from southeast Asian countries. Environ Sci Pollut Res 26: 13210–13220 DOI 10.1007/s11356-019-04829-4.
34. Kluza K, Ziolo M, Bąk I, Spoz A (2021) Achieving Environmental Policy Objectives through the Implementation of Sustainable Development Goals. The Case for European Union Countries. Energies 14(8): 1-23.
35. Kroll C, Warchold A, Pradhan P (2019), Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies?. Palgrave Commun 5:140 DOI 10.1057/s41599-019-0335-5.
36. Krueger R, Gibbs D (2007) The Sustainable Development Paradox: Urban Political Economy in the United States and Europe, Guilford Press, New York.

37. Lapinskienė G, Peleckis K, Slavinskaitė N (2017) Energy Consumption, Economic Growth and Greenhouse Gas Emissions in the European Union Countries. J. Bus. Econ. Manag. 18: 1082–1097 DOI 10.3846/16111699.2017.1393457.
38. Lawrence J, Blackett P, Cradock-Henry NA (2020) Cascading climate change impacts and implications. Climate Risk Management 29/(100234) DOI 10.1016/j.crm.2020.100234.
39. Lebel L (2014) Closing knowledge - action gaps in adaptation to climate change in the Asia-Pacific region. Environment and Sustainable Development 13: 204–222. DOI 10.1504/IJESD.2014.060222
40. Lee KH, Min B, Yook KH (2015) The impacts of carbon (CO2) emissions and environmental research and development (R&D) investment on firm performance. Int. J. Prod. Econ. 167: 1–11.
41. Levinson A (2012) Valuing public goods using happiness data: the case of air quality. J. Public Econ. 96: 869–880.
42. Li S, Meng J, Zheng H, Zhang N, Huo J, Li Y, Guan D (2021) The driving forces behind the change in energy consumption in developing countries. Environmental Research Letters 16(5): 054002.
43. Liu CG, Cai W, Zhang CX, Ma M, Rao W, Li W et al. (2018) Developing the ecological compensation criterion of industrial solid waste based on energy for sustainable development. Energy157: 940–948.
44. Locatelli B, Aldunce P, Fallot A, Le Coq JF, Sabourin E, Tapasco J (2017) Research on Climate Change Policies and Rural Development in Latin America: Scope and Gaps. Sustainability9: 1831. DOI 10.3390/su9101831
45. López R, Palacios A (2014) Why has Europe become environmentally cleaner? Decomposing the roles of fiscal, trade and environmental policies. Environ. Resour. Econ. 58: 91–108.
46. Meadows DH, Randers J, Meadows DL (2004) The Limits to Growth: the 30-Year Update (Universe Books, New York).
47. Mavisakalyan A, Tarverdi Y. (2018) Gender and climate change: Do female parliamentarians make difference? European Journal of Political Economy, 56, 151-164.
48. Murray J (2020) SUERF Mother Nature: The gender-climate nexus. Policy Note, 151 https://www.suerf.org/policynotes/11317/mother-nature-the-gender-climate-nexus(access: 17.12.2021).
49. Nasir M, Rehman, FU (2011) Environmental Kuznets curve for carbon emissions in Pakistan: An empirical investigation. Energy Policy 39: 1857–1864.
50. Niu T, Yao X, Shao S, Li D, Wang W (2018) Environmental tax shocks and carbon emissions: An estimated DSGE model. Struc Chan Econ Dyna. 47: 9–17.
51. O'Neill DW, Fanning AL, Lamb WF, Steinberger JK (2018) A good life for all within planetary boundaries. Nat. Sustain. 1: 88–95.
52. OECD (2019) Accelerating Climate Action Refocusing policies through a well-being lens, Paris.
53. Oehlert GW (2010) A first Course in Design and Analysis of Experiments. University of Minnesota: Saint Paul MN USA.
54. PCC (2018), Global warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.
55. Pedercini MS, Arquitt D, Collste HH (2019) Proceedings of the National Academy of Sciences Nov 116/(46): 23021-23028 DOI 10.1073/pnas.1817276116.
56. Piciu GC, Tric CL (2012) Assessing the impact and effectiveness of environmental taxes. Proc Econ Finance 3: 728–733.
57. Postuła M, Radecka-Moroz K (2020) Fiscal policy instruments in environmental protection. Environmental Impact Assessment Review 84/(106435) DOI 10.1016/j.eiar.2020.106435.
58. Pradhan P, Costa L, Rybski D, Lucht W, Kropp JP (2017) A systematic study of sustainable development goal (SDG) interactions. Earth's Future *5*(11): 1169-1179.
59. Rehfeld KM, Rennings K, Ziegler A (2007) Integrated product policy and environmental product innovations: An empirical analysis. Ecological Economics 61(1): 91–100 DOI 10.1016/j.ecolecon.2006.02.003

60. Renaud F, Zhou X, Bosher L et al. (2020) Synergies and trade-offs between sustainable development goals and targets: innovative approaches and new perspectives. Sustain Sci 15: 1011 DOI 10.1007/s11625-020-00815-9
61. Repke MA, Berry MS, Conway LG 3rd, Metcalf A, Hensen RM, Phelan C (2018) How does nature exposure make people healthier?: Evidence for the role of impulsivity and expanded space perception. PLoS One. 13(8): e0202246 DOI 10.1371/journal.pone.0202246.
62. Riti JS, Song D, Shu Y, Kamah M (2017) Decoupling CO2 emission and economic growth in China: Is there consistency in estimation results in analyzing environmental Kuznets curve?. Journal of Cleaner Production, 166: 1448–1461.
63. Roberts JT et al. (2020) Four agendas for research and policy on emissions mitigation and well-being. Glob. Sustain. 3.
64. Saidi K, Mbarek MB (2016) Nuclear energy, renewable energy, CO2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests. Progress in Nuclear Energy 88: 364–374.
65. Salari M, Javid RJ, Noghanibehambari H (2021) The nexus between CO2 emissions, energy consumption, and economic growth in the U.S. Economic Analysis and Policy 69: 182-194 DOI 10.1016/j.eap.2020.12.007.
66. Scherer L et al. (2018) Trade-offs between social and environmental sustainable development goals. Environ. Sci. Policy 90: 65–72.
67. Shahbaz M, Mahalik MK, Shah SH, Sato JR (2016a) Time-varying analysis of CO2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. Energy Policy 98: 33–48.
68. Shahbaz M, Shahzad SJH, Ahmad N Alam S (2016b) Financial development and environmental quality: The way forward. Energy Policy 98: 353–364 DOI 10.1016/j.enpol.2016.09.002.
69. Sheraz M, Deyi X, Ahmed J, Ullah S, Ullah A (2021a) Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from G20 countries. Environmental Science and Pollution Research 1-19.
70. Sheraz M, Deyi X, Mumtaz MZ, Ullah A (2021b). Exploring the dynamic relationship between financial development, renewable energy, and carbon emissions: A new evidence from belt and road countries. Environ Sci Pollut Res DOI 10.1007/s11356-021-16641-0
71. Staszczyk A (2017). Stacjonarność danych panelowych a konwergencja cenowa na przykładzie importu do krajów UE. Studia Ekonomiczne 324: 129-141.
72. Sterpu M, Soava G, Mehedintu A (2018) Impact of Economic Growth and Energy Consumption on Greenhouse Gas Emissions: Testing Environmental Curves Hypotheses on EU Countries. Sustainability 10/(3327) DOI 10.3390/su10093327.
73. Tamazian A, Chousa JP, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. Energy Policy 37: 246–253 DOI 10.1016/j.enpol.2008.08.025.
74. Tamura H, Nakanishi R, Hatono I, Umano M (1996) Is environmental tax effective for total emission control of carbon dioxide?: Systems analysis of an environmental - economic model. IFAC 29(1): 5435–5440.
75. Urbaniec M, Tomala J, Martinez S, (2021) Measurements and Trends in Technological Eco-Innovation: Evidence from Environment-Related Patents. Resources 10/(68) DOI 10.3390/resources10070068.
76. Zhang Q, Prouty C, Zimmerman JB, Mihelcic JR (2016) More than Target 6.3: A Systems Approach to Rethinking Sustainable Development Goals in a Resource-Scarce World. Engineering 2: 481–489.
77. Ziolo M, Kluza K, Kozuba J, Kelemen M, Niedzielski P, Zinczak P (2020) Patterns of Interdependence between Financial Development, Fiscal Instruments, and Environmental Degradation in Developed and Converging EU Countries. International Journal of Environmental Research and Public Health, 17(12): 1-17.
78. Zou S, Zhang T, (2020). CO2 emissions, energy consumption, and economic growth nexus: evidence from 30 provinces in China. Mathematical Problems in Engineering, Article ID 8842770.

Figures

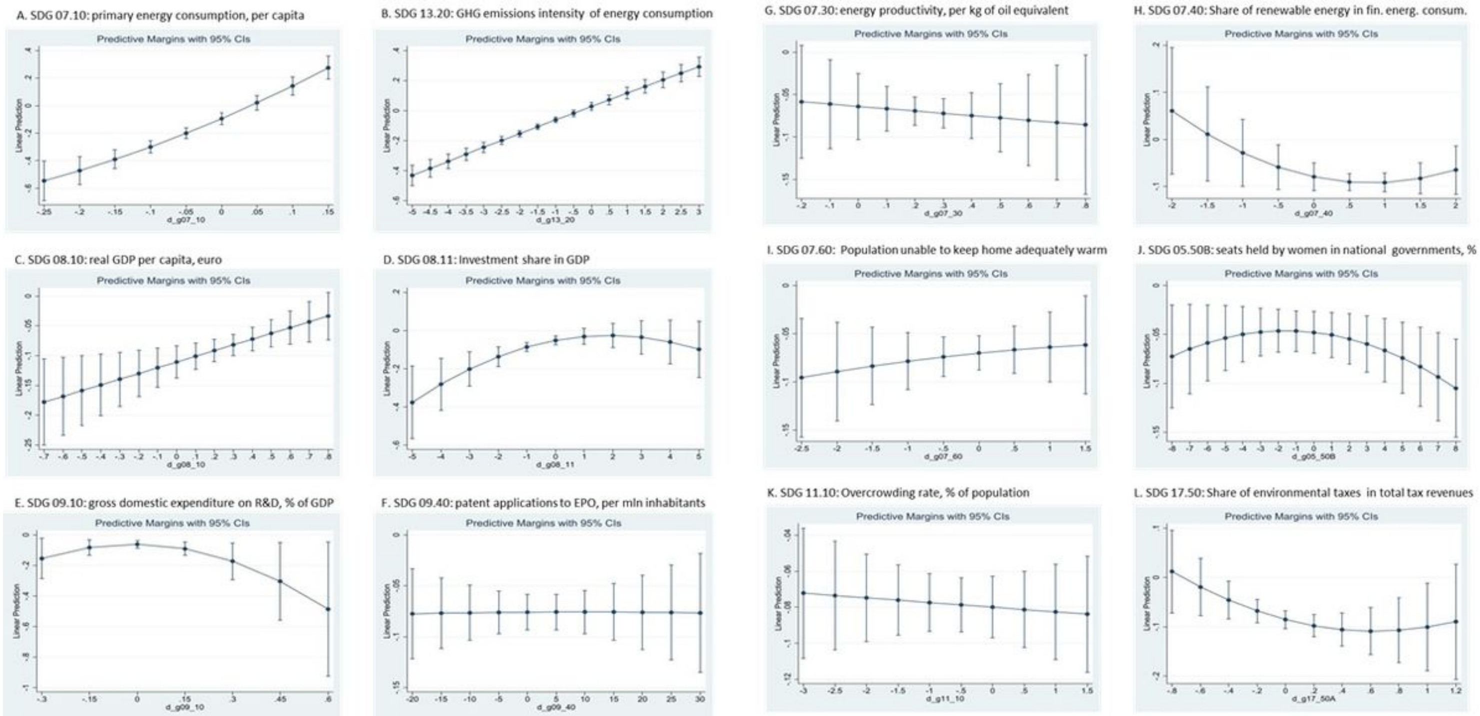

Figure 1

Charts A-F. Marginal effects of selected SDG indicators in Model 2

Charts G-L. Marginal effects of selected SDG indicators in Model 2

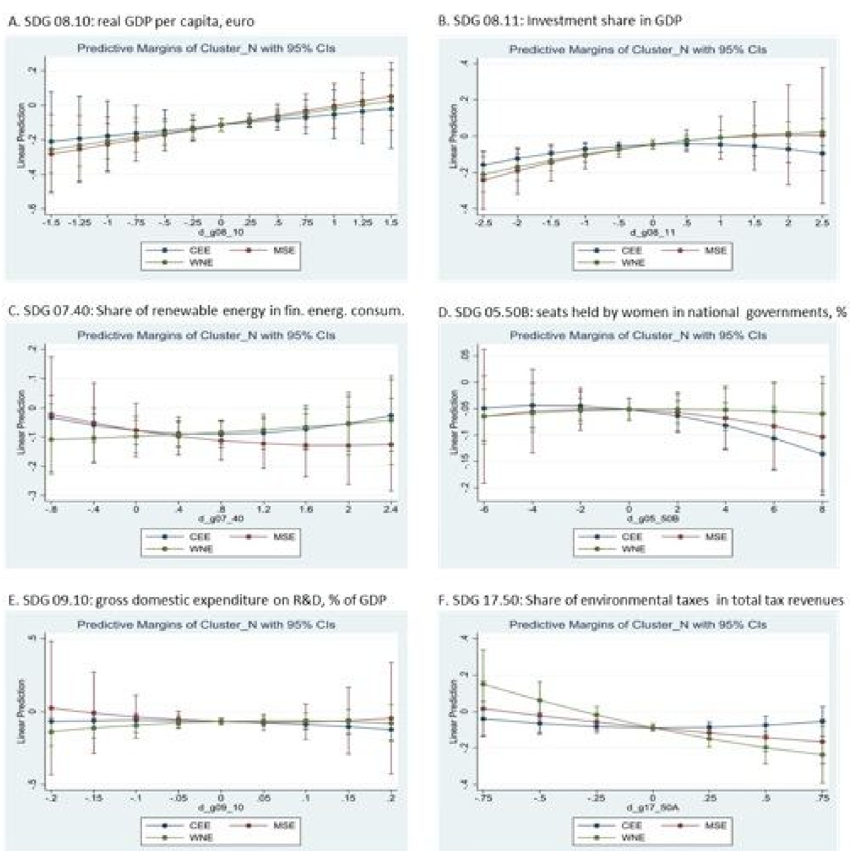

Figure 2

Charts A-F. Marginal effects of selected SDG indicators modelled with 2-way interactions with geographical clusters

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