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Do bureaucratic policy and socioeconomic factors moderate energy utilization effect of net zero target in the EU?

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A R T I C L E I N F O

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A B S T R A C T

Based on the commitment to improve environmental quality across European Union under the United Nations' Sustainable Development Goals and varying national goals, this study investigates the dynamic linkages between bureaucracy, socioeconomic factors, conventional fossil fuel energy consumption vis-à-vis aggregate fossil and disaggregate fossil (oil, coal, and gas) fuels and environmental quality in the panel of selected 25-EU nations for the period 1990–2017. The study employs relevant second-generation empirical method and unearth the following results: (1) inverted environmental Kuznets curve was validated while fossil fuel consumption has a deteriorating impact on environmental performance due to its positive effect on carbon emission; (2) fossil fuel energy consumption (both aggregate and it components) exerts a dampening impact on environmental performance due to its positive effect on carbon emission; (3) that direct effect of bureaucracy and socioeconomic factors promote environmental quality but the degree or magnitude of influence is significantly different between bureaucratic system and socioeconomic factor, and (4) the moderating or indirect impact of bureaucracy, socioeconomic on the environment via fossil fuel energy consumption is observed and significantly different across the model specification. Moreover, the result reveals a unidirectional causal relationship flows from GDP per capita, bureaucracy and socioeconomic factors to carbon emission, while bi-directional relationships between oil, gas and carbon emission are established. In policy direction, the study therefore recommend that the European Union member countries should further explore the opportunities in clean energy development in order to ameliorate the continent's environmental concerns. Furthermore, in the quest to scale up the bloc's energy transition, significant improvement in the countries' bureaucracy establishment and socioeconomic conditions could hasten the energy transition and efficiency policy while improving the environmental sustainability drive.

1. Introduction

Although European Union (EU) has achieved progress in term of its environmental sustainability agenda, the continent contributes more to global greenhouse gas emissions than Africa despite having a lesser population, estimated at 748 million in 2021 compared to Africa's total population estimated at 1.3 billion in 2021. Statistics from the European Environment Agency (EEA) confirm that the present value of the total greenhouse gas emissions in the European Union is 23.2% lower compared to the value in 1990 and also that the contribution of the European Union to global greenhouse gas emissions has decreased from 15% to 8% over 1990–2018. Despite this immaculate achievement, environmental experts, environmental NGOs and think-tanks have berated the EU on its new policy announcement of a 55% carbon emissions reduction target by 2030 on the following counts: (a) the 55% carbon emission (CEM) target is below the recommendation of a 60% CEM reduction target by the European Parliament environment committee of September 2020 and it is insufficient to actualize the Paris

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Agreement's target of below 1.5 °C by 2050; (b) government bureaucracy withholding the consideration of increasing the EU's carbon emission reduction target to 65% in line with the proposal of the European Parliament's rapporteur for climate law.

The justification for studying the EU's use of fossil fuels arises from the increasing dependence of EU member states on the importing of fossil fuels, especially from non-EU member states. This action has further raised questions about the risks associated with the security of the energy supply within EU countries and other economies (Aldieri et al., 2021). Critical examples such as the natural gas transport pipeline under the auspices of the European Network of Transmission System Operators for Gas (ENTSOG) show that the energy demands are still largely by fossil fuels in most EU countries. For instance, despite meeting the 10% target in 2020, the purported switch to renewable energy for the EU transport sector is still about 10.2%. Despite the Eurostat figures obtained from the EU statistical pocketbook 2021 on the share of EU energy production by source showing that renewable energy and nuclear energy constitute a combined 68.4% alongside the recorded improvement in vehicle efficiency, the EU transport sector is still reliant on fossil fuels which negates the 90% reduction target goal for transport emissions by 2050 for the European Union.

The case of bureaucracy was based on the unanimous decision of the populace to give up decision-making responsibilities to selected individuals, mostly unelected, which has resulted in a threat and inefficiency posed to the citizens, government, and the environment. The case of the European Union and its climate change goals portrays setbacks in the climate target attainment owing to the complex permission processes, country-specific conflicting goals, red-tapism, and overregulation in both the home countries and the EU. Italy strikes the perfect example by illustrating how red-tapism has altered their transitioning from nonrenewable to renewable energy. The goal of installing 40 GW h of renewable energy in the country to accelerate decarbonization by 2050 has been thwarted by an overly complicated permission process opined to take up to six years. Despite the EU's renewable energy directive stating 3 years as the maximum period for granting permits for power plants, implementation is not yet feasible (see EUCA Special Report, 2019). In the case of Germany, low bureaucratic expertise, cumbersome administrative procedures, public resistance, legal tussles, environmental concerns, political issues, and rigid environmental laws have increased the duration of the permitting process for a variety of renewable energy projects (see Baur et al., 2022; Euractiv, 2020; ReutersEvents, 2021). Cutting down on the duration of the permit processesing, volume of environmental regulations, and a higher level of bureaucratic expertise will hasten the progress of using more renewable energy (see EEA, 2019). The purpose of this study is to examine the dynamic linkages between bureaucracy, socioeconomic factors, economic growth, fossil fuel consumption, and environmental quality in the selected 25 EU nations.

This research differs from the previous studies in the following areas: 1.) From the literature perspective, this study is the first to examine the combined role of bureaucracy and socioeconomic factors in relation to carbon emissions in the European Union, further extending to their direct and indirect effect on carbon emissions through fossil fuel energy consumption. However, previous studies like those of Alola et al. (2019), Levay et al. (2021), Sarwar and Alsaggaf (2021) and Povitkina (2015) have considered bureaucracy and socioeconomic variables to be standalone variables in a model. 2.) To comply with the EU policy on net-zero carbon emissions by 2050, this study will unearth the role of bureaucracy and socioeconomic factors on fossil fuel consumption. In addition, this study will address the case of how efficient EU countries are utilizing fossil fuels (oil gas and coal) under the influence of bureaucracy and socioeconomic factors to protect their environment. In this direction, our study differs from those of Albulescu et al. (2019), Adedoyin et al. (2020), and Boluk and Mert (2014) who have investigated the transitioning process from traditional fossil fuels to renewable energy without considering the quality of the bureaucratic expertise involved and mundane socioeconomic factors, which is relevant in the case of European Union. Lastly, we consider the emerging econometric problems as part of the country-specific characteristics such as cross-sectional dependencies, endogeneity, and multicollinearity. We implement the second-generation panel unit root, Westerlund, panel cointegration test, Dynamic common correlated effect mean group (DCEMG) estimators, augmented mean group (AMG) estimator, and the Dumitrescu and Hurlin (D-H) non-causality test to eliminate the issues of slope heterogeneity and cross-sectional dependencies.

This study is arranged as follows. Next is a review of the related literature on the subject matter, followed by the research and econometric methodologies. The study outcomes are given in the section on the empirical results and discussion of findings. Finally, the closing section is comprised of the summary of the findings and policy implementation.

2. Methodology and data description

Our study utilizes balanced and yearly data from 1990 to 2017 from the estimated series of 25 EU countries (Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, and the UK). The choice of countries and data is largely due to the EU policy on a net zero target by 2050 and the limited data on fossil fuel consumption respectively. By following an existing empirical model, the modified empirical specification adopted for the current study forms the basis and analysis of the investigation.

2.1. Model specification and justification

Theories capturing the drivers of environmental quality include the environmental Kuznets curve (EKC) hypothesis, carbon curse theory, and the principle of "pollute now and grow later." The carbon curse theory, with its primer proponents by Friedrichs and Inderwildi (2013), documents that fossil-fuel rich countries are associated with high carbon intensity levels. This study builds on the modelling protocol from the extant literature, (Bekun et al., 2019; Ghazali and Ali, 2019; Muoneke et al., 2022; Okere et al., 2021a,b, 2022; Saint Akadiri et al., 2019, 2020, 2021). GDP per capita reportedly plays a major part in carbon emissions under the theory of growth-induced EKC. However, there are other human activities that either mitigate or aggravate carbon emission (environmental degradation) and as such could happen through the indirect effect of bureaucratic policy and socioeconomic factors. Accordingly, we incorporate these two variables in the modelling of carbon emissions, thus our baseline models for this empirical adventure are expressed as:

$$CEM_{it} = f\left(gdp_{i,t}, gdpsq_{i,t}, fossil_{i,t}, fossil_{i,t}, * bur_{i,t}, bur\right) \tag{1}$$

$$CEM_{it} = f\left(gdp_{i,t}, gdpsq_{i,t}, fossil_{i,t}, fossil_{i,t}, * soc_{i,t}, soc\right) \tag{2}$$

From equations (1) and (2) above, t indicates the time index and i indicates the country index. To explain the factors that drive carbon emission: (i) we disaggregate fossil fuel consumption into three components following our empirical discussion oil consumption (oil), coal consumption (coal) and natural gas consumption (gas); (ii.) we account for the indirect role of bureaucracy (bur) and socioeconomic factors (soc) to account their direct environmental impact; (iii.) the interaction between fossil fuel consumption and bureaucracy $(fossil * bur)$ and fossil fuel consumption and socioeconomic factors $(fossil * soc)$ were examined to account for their indirect effects on carbon emission. *gdp and gdpsq* represents real GDP per capita and its square that account for EKC. The log-linear empirical replication of the above equations (1) and (2) is shown as thus:

$$lnCEM_{it} = \beta_0 + \beta_1 lngdp_{i,t} + \beta_2 lngdpsq_{i,t} + \beta_3 lnfossil_{i,t} + \beta_4 ln(fossil_{i,t} * bur_{i,t}) + \beta_5 lnbur_{i,t} + \varepsilon_{it} \tag{3}$$

$$lnCEM_{it} = \alpha_0 + \alpha_1 lngdp_{i,t} + \alpha_2 lngdpsq_{i,t} + \alpha_3 lnfossil_{i,t} + \alpha_4 ln(fossil_{i,t} * soc_{i,t}) + \alpha_5 lnsoc_{i,t} + \mu_{it} \tag{4}$$

where $\beta_1 \ldots\ldots\beta_5$ are coefficients to be estimated, $\beta_0 or\, \alpha_0$ are the intercept and ε is the stochastic error term in the model. The *ln* is the natural logarithm that informed the coefficients and ease the interpretation of the result. There are five possible ways interpreting EKC hypothesis in equations (3) and (4) with respect to gdp and gdpsq: If $\beta_1 or\, \alpha_1 = 0, and\, \beta_2\, or\, \alpha_2 = 0$ there is no significant relationship between GDP per capita and carbon emission. If $\beta_1 or\, \alpha_1 > 0, and\, \beta_2\, or\, \alpha_2 > 0$ there is linearly increasing relationship. $\beta_1 or\, \alpha_1 < and\, \beta_2\, or\, \alpha_2 < 0$ There is linearly decreasing relationship. If $\beta_1 or\, \alpha_1 > 0\, and\, \beta_2\, or\, \alpha_2 < 0$, there is presence Inverted U-shape relationship. If $\beta_1 or\, \alpha_1 < and\, \beta_2\, or\, \alpha_2 > 0$, there is presence of U-shape relationship. $\beta_3 or \alpha_3$ in equations (3) and (4) is expected to be positive and that will indicate that fossil fuel consumption aggravates carbon emission. β_5 or α_4 is expected to be negative and that will indicate that bureaucracy and socioeconomic factor mitigate carbon emission. $(fossil_{i,t} * bur_{i,t})$ and $ln(fossil_{i,t} * soc_{i,t})$ are the interaction term, measuring the combined effect of bureaucracy and fossil fuel consumption, and socioeconomic and fossil fuel consumption on carbon emission respectively. Accordingly, the combined effect/interaction term of bureaucracy and fossil in equation (3) will lead to a decreasing effect on carbon emission if $\beta_4 < 0$. Similarly, the combined effect/interaction term of socioeconomic factor and fossil in equation (4) will lead to decreasing effect on carbon emission if $\alpha_4 < 0$. However, the positive effect in equations (3) and (4) suggest that the interaction between the variables aggravate environmental degradation.

2.1.1. Data description

Because of data restriction, the study is limited to the balanced panel of 25 countries from 1990 to 2017. The carbon emission (CEM) is used as a proxy for environmental quality; GDP is gross domestic product per capita (constant 2010 US$), denoted as GDP and its square is used to capture the traditional growth-induced EKC hypothesis. Three indicators of fossil fuel consumption/non-renewable energy source are: oil consumption, coal consumption and natural gas consumption. The bureaucracy (bur) and socioeconomic factors (soc) are the additional explanatory variables that were retrieved from the Political Risk Services (https://www.prsgroup.com/explore-our-products/international-country-risk-guide/), while the other aforementioned variables are from the British Petroleum database. For the detailed explanation of the variable, see Table 1 while the step-by-step description of the methods are highlighted in Fig. 1.

Step 1: We investigate one of the biggest problems in cross-country study is that of cross-sectional dependence (CSD) in panel data set and model residual simultaneously. This examination is vital because of the deep interconnection between the countries. Accordingly, Pesaran (2004) CSD test is employed to verify the CSD in the variables and panel model residuals under the null hypothesis of CSD test as thus: $H_o : \hat{p}_{ik} = corr(\varepsilon_{it}\varepsilon_{kt}) = 0 \forall i \neq k$ while Pesaran (2004) cross-section dependent test is as thus:

$$CSD = \sqrt{\frac{2T}{n(n-1)}} \left(\sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \hat{p}_{ik} \right) \sim n(0,1)\; i,\; k \tag{5}$$

$$CSD = (1, 2, \ldots\ldots\ldots\ldots\ldots\ldots N)$$

$\hat{p}_{ik}$ in equation (5) introduces the ADF assessment with respect to the pairwise cross-sectional connection.

Table 1
Data description.

Abbreviation	Definition	Unit of measurement	Data source
lncem	log of carbon emission	million tonnes of CO2 emissions	BP
lngdp	log of GDP per capita	GDP per capita (constant 2010 US$)	WDI
lngdpsq	log of GDP per capita square	It measures the square of GDP per capita	WDI
lnoil	Natural log	Million tonnes per capita expressed in 2010 constant US dollars	BP
lncoal	Natural log	Million tonnes per capita expressed in 2010 constant US dollars	BP
lngas	Natural log	Million tonnes per capita expressed in 2010 constant US dollars	BP
Lnbur	Natural log	Bureaucracy stands for the institutional quality, strength and shock absorber that tends to reduce monotonic government policy change. High points = 4, and low points = 1 for nations with high or low strength and expertise to govern with minimal changes in policy.	ICRG
lnoilbur	Natural log	Interaction term	BP/ ICRG
lnsoc	Natural log	Social-economic factor stands for the constrain on government action on policymaking. The risk rating is the total of three subcomponents: Unemployment, Consumer Confidence, Poverty, each with a maximum score of four points and a minimum score of zero. Very Low Risk is a 4-point scale, with 0 points representing extremely high risk.	ICRG
lnoilsoc	Natural log	Interaction term	BP/ ICRG
lncoalbur	Natural log	Interaction term	BP/ ICRG
lncoalsoc	Natural log	Interaction term	BP/ ICRG
lngasbur	Natural log	Interaction term	BP/ ICRG
lngassoc	Natural log	Interaction term	BP/ ICRG

Sources: Author's compilation. WDI is world Bank Development Indicator, ICRG is International country Risk Guide. List of all variable definitions | The PRS Group. BP Statistical Review of World Energy (2020)

Step 2: We proceed by testing for panel unit root given the presence of cross-sectional dependence in the data series that may generate spurious result (Im et al., 2003) leading nullification of 1st generation estimation procedure. Therefore, the researcher adopts cross-sectional augmented Im, Pesaran, and Shin (CIPS) and cross-sectional augmented Dickey-Fuller (CADF) tests orchestrated by Pesaran (2007). This technique is credited for accounting for heterogeneity and assumes cross-sectional dependence. The null hypothesis under this technique is that variables are not stationary. The equation for the CIPS and CADF are stated as:

$$\Delta Y_{it} = \omega_i + \rho_i^* Y_{i,t-1} + d_0 \overline{Y}_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta \overline{Y}_{t-j} + \sum_{j=1}^{p} c_{ij} \Delta Y_{i,t-j} + \varepsilon_{it} \tag{6}$$

The difference operator is Δ, Y is the target variable, $i = 1, \ldots\ldots N$ represent the countries considered over $t = 1, \ldots\ldots\ldots T$, ε_{it} is the stochastic error term. CIPS statistics is estimated as thus:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} CADF_i \tag{7}$$

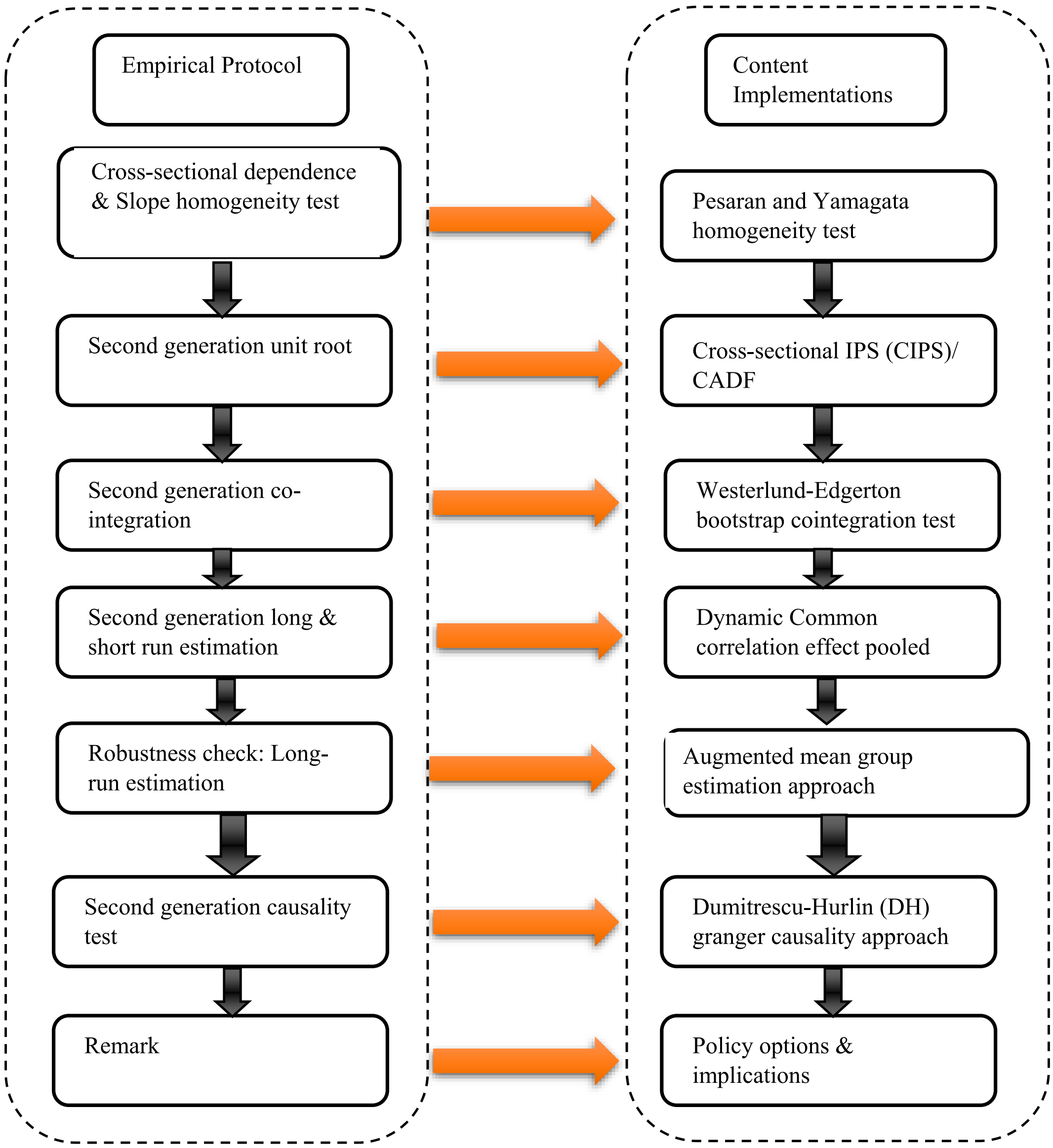

Fig. 1. Schematic path of the study.
Sources: author's design.

Step 3: The Pesaran and Yamagata (2008) test for slope homogeneity of the estimates are carried. The assumption is that a situation where the slope coefficients are confirmed heterogeneous but falsely assumed to homogenous, such leads to bias estimates. This produces Delta tilde $(\widetilde{\triangle})$ and bias-adjusted delta tests $(\widetilde{\triangle}_{Adj})$ for slope homogeneity that offers whether the slope coefficients are heterogeneous under the null hypothesis of homogeneous slope coefficients.

Step 4: Cointegration Procedure: this study employs the Westerlund (2007) approach to offer insight about cointegration among the variables. The error rectification method (ECM) of the estimation is presented as thus:

$$\Delta Y_{i,t} = \gamma_i' d_t + \alpha_i\left(Y_{i,t-1} - \beta_i' X_{i,t-1}\right) + \sum_{m=1}^{k} \partial_{im} \Delta Y_{i,t-m} + \sum_{m=1}^{k} \varphi_{im} \Delta X_{i,t-m} + \varepsilon_{it} \tag{8}$$

where.

α_i is the adjustment coefficient indicating the error coefficient term and speed of correction towards the equilibrium. $Y_{i,t}$ and $X_{i,t}$ are the dependent and independent variables, Δ is difference operator. We expect to get four different tests from Equation (8) above from the estimation.

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\widehat{\alpha}_i}{se(\widehat{\alpha}_i)} \tag{9}$$

$$G_a = \frac{1}{N} \sum_{i=1}^{N} \frac{T\widehat{\alpha}_i}{1 - \sum_{m=1}^{K} \alpha'_{im}} \tag{10}$$

$$P_t = \frac{\widehat{\alpha}}{se(\widehat{\alpha})} \tag{11}$$

$$P_a = P\widehat{\alpha} \tag{12}$$

G_t *and* G_a are the group statistics employed to predict the null hypothesis of non-cointegration that exit in at least one of the cross-sections ($H_O: \alpha_i = 0$ for all value of i) against the alternative ($H_1: \alpha_i < 0$ for at least$i$). On the other hand, panel statistics (P_t and P_a) pool information in all the cross sectional units to predict the null hypothesis ($H_O: \alpha_i = 0$ for all value of i) against the alternative ($H_1: \alpha_i < 0$ for all i) offer a path for identifying the presence of cointegration for the whole panel.

Step 5 The Dynamic Common Correlated Effects (DCCE) estimator was employed to estimate the model specification in equations (3) and (4). This technique was proposed by Chudik and Pesaran (2015) with the aim of solving the problem of cross-sectional dependence and efficient for estimation of both short-run and long-run results can be estimated for heterogeneous panels date set. It is based on the standards of PMG estimation designed by Pesaran et al. (1999), MG estimation of Pesaran and Smith (1995), and common correlated effects (CCE) method presented by Pesaran (2007) and have carefully implemented by Chaudhry et al., 2021; Sharma et al. (2021); Ali et al. (2021).

The DCCE can be expressed as thus

$$Y_{it} = \beta_i Y_{it-1} + \delta_i X_{it} + \sum_{P=0}^{P_T} \gamma_{xip} \overline{X}_{t-p} + \sum_{P=0}^{P_T} \gamma_{yip} \overline{X}_{t-p} + \varepsilon_{it} \tag{13}$$

A one-period lag has been incorporated in the model in order to account for the delay between the length of time that it takes for carbon emission to reach its long-term equilibrium. where, Y_{it} and Y_{it-1} represent the dependent variable and the lag of the dependent variable which employed to serve as an independent variable. X_{it} is a vector of independent variables, while γ_{xip} and γ_{yip} are the unobserved common factors. P_T and ε_{it} represent the lags of the cross-sectional averages and stochastic error term i and T are the number of cross section and time dimensions. A robust analysis is carried using Eberhardt and Bond (2009) AMG estimator that deals with the issue of cross-sectional dependence through the common dynamic process.

Step 6: Finally, the Dumitrescu and Hurlin (2012) D-H causality test that accommodates heterogeneity and CSD in the series was employed to access the direction of causal between the panel date set. Accordingly, X and Y to be the independent and the dependent variables respectively, then the D-H causality test is expressed

$$Y_{it} = \varphi_i + \sum_{k=1}^{k} \varnothing_{ik} Y_{i,t-k} + \sum_{k=1}^{k} \delta_{ik} X_{i,t-k} + \varepsilon_{it} \tag{14}$$

where.

$\varnothing_{ik}$ and δ_{ik} are coefficients of $Y_{i,t-k}$ and $X_{i,t-k}$ and the $H_o: \ \delta_{i1} = \ldots = : \ \delta_{ik} = 0, \forall_i = 1, \ldots, N$ is tested against the alternative hypothesis $H_1: \delta_{i1} = \ldots =: \ \delta_{ik} = 0, \forall_i = 1, \ldots, N_1$ with $\delta_{i1} \neq$ or … or $\delta_{ik} \neq 0 \ \forall_i = N_1 + 1, \ldots, N$. Also, N_1 is a natural number that satisfies the condition: $0 \leq \frac{N_1}{N} \leq 1$. Further, the panel data set is expected to balance with k the lag in the units. Two statistics $\overline{W}$- statistics and Z-statistics are computed from D-H causality test as thus;

$$W_{N,T}^{HNC} = N^{-1} \sum_{i=1}^{N} W_{i,t} \tag{15}$$

$$W_{N,T}^{HNC} = \frac{\frac{1}{\sqrt{N}} \left[\sum_{i=1}^{N} W_{i,t} - \sum_{i,1}^{N} E\left(W_{i,t}\right) \right]}{\sqrt{\frac{1}{N} \sum_{i=1}^{N} VAR\left(W_{i,t}\right)}} \tag{16}$$

where, $W_{i,t}$ account for cross-sectional Wald statistics. $E(W_{i,t})$ and $VAR(W_{i,t})$ represent the expectation of cross-sectional Wald statistics and its variance respectively.

3. Empirical analysis and discussion

Table 2 show the preliminary tests that include the descriptive statistics and the correlation matrix of the variables of interest. According to the descriptive statistics, it is clear that gdp and gdpsq occupy the greatest value, whereas the interaction term of coal and bureaucracy has the lowest value. The correlation matrix shows that the level of carbon emissions, as well as the GDP per capita, oil, coal, and gas, have a moderately strong positive connection. These preliminary findings suggest that as fossil fuel consumption increases and as the GDP per capita increases, so too do the emissions of carbon dioxide. Bureaucracy

Table 2
Descriptive statistics and correlation matrix.

Variable	lncem	lngdp	lngdpsq	lnoil	lncoal	lngas	lnbur	lnooillbur	lnsoc	lnoilsoc	lncoalbur	lncoalsoc	lngasbur	lngassoc
Mean	1.8920	11.3677	129.6386	1.0920	−0.6966	−0.6329	0.6013	0.6645	0.8356	0.9306	−0.4330	−0.5817	−0.3783	−0.5137
Std. Dev.	0.5373	0.6434	14.6387	0.5563	0.7088	0.6644	0.1236	0.3768	0.1232	0.5180	0.4932	0.6112	0.4247	0.5612
Min	0.8388	9.9960	99.9204	0.0438	−2.7761	−2.7359	0.3010	0.0209	0.1249	0.0315	−2.1179	−2.7340	−1.7409	−2.2044
Max	3.0033	12.5886	158.4731	2.1377	0.7409	0.5649	0.7782	1.4984	1.0414	2.0546	0.4461	0.5924	0.4374	0.5854
Obs	700	700	700	700	700	700	700	700	700	700	700	700	700	700
lncem	1													
lngdp	0.5984	1												
lngdpsq	0.6001	0.1995	1											
lnoil	0.7435	0.3505	0.4523	1										
lncoal	0.5878	0.1097	0.3951	0.4276	1									
lngas	0.6358	0.4741	0.4788	0.5946	0.6445	1								
lnbur	−0.005	0.1783	0.1728	0.1147	−0.161	0.0274	1							
lnoilbur	−0.856	0.3926	0.2927	0.4272	0.2402	0.2198	0.4287	1						
lnsoc	−0.161	0.4075	0.4036	0.2649	0.0041	0.1854	0.3428	0.3254	1					
lnoilsoc	−0.897	0.1561	0.2583	0.2706	0.4652	0.5793	0.1683	0.2182	0.4641	1				
lncoalbur	−0.832	0.2137	0.4132	0.3594	−0.5076	0.4073	−0.3184	0.2419	−0.0805	0.5914	1			
lncoalsoc	−0.846	0.2623	0.2235	0.4799	0.4767	0.3194	−0.2236	0.3847	−0.1558	0.597	0.3793	1		
lngasbur	−0.6186	0.3846	0.2907	0.2313	0.6959	−0.4516	−0.1958	0.2218	0.0745	0.3036	0.2101	0.1947	1	
lngassoc	−0.825	0.4222	0.4029	0.4691	0.3583	−0.4784	−0.0482	0.6811	0.0243	0.2305	0.6431	0.1704	0.2625	1

Sources: Author's compilation

and socioeconomic factors have a negative correlation with carbon emissions and a positive correlation with GDP per capita.

The results of the CD test and a more recent unit test for the variables are then reported accordingly in Table 3. Pesaran's (2004) CD test rejects the null hypothesis for all variables at a 1% significance level, indicating that all variables are cross-sectionally dependent. This result suggests strong evidence of the cross-sectional dependence problem. The presence of cross-sectional dependence in the variables may lead to spurious estimations. In line with Pesaran (2007), the CADF and CIPS panel unit root test was employed to check for the order of integration of the variables. It is important to ensure that the appropriate methodology is implemented which ensures reliable and unbiased estimates. The synopsis from Table 3 avails that the variables are integrated in order and are mixed, for instance *lnoil, lncoal, lngas, lnoilbur,* and *lnsoc* are I(0) while the rest are in I(1). The slope homogeneity tests were the next in line after confirming the cross-sectional dependency and stationarity test steps 1 & 2 as in the above paragraph. Table 4 reports the results of the Pesaran and Yamagata (2008) Delta tilde ($\widetilde{\triangle}$) and adjusted delta ($\widetilde{\triangle}_{Adj}$) tests for slope homogeneity. The null hypotheses were rejected, confirming that the slope coefficients are homogeneous at a 1% significance level for all specifications. This implies the presence of heterogeneity in the panel data set. It makes the use of Westerlund's test (2007), also known as the second-generation cointegration test.

In Table 5, the error-correction panel cointegration test (Westerlund, 2007) is implemented in line with the existing repositories (Anser et al., 2021; Anser et al., 2021), validating the long-run association among the variables employed in this study. Accordingly, the group (G_a and G_t) and panel (P_a and P_t) tests are adequate enough to reject the null hypothesis and affirm the long-run association among the data set. To account for the presence of cross-section dependency and slope heterogeneity in the panel data set designed for this empirical adventure, we employed the DCCE estimator for this study and re-examined the analysis using AMG, which is robust and consistent with the recently developed empirical and analytical tool.

3.1. Main empirical results

This study involves the preliminary investigation based on the EU environmental policies targeting net-zero carbon emissions.

Table 6 above reports the impact of bureaucracy and socioeconomic factors on fossil fuel consumption (oil, coal, and gas) in the EU member countries. There is a negative impact due to bureaucracy and socioeconomic factors on fossil fuel consumption across the three specifications. Specifically, a 1% rise in bureaucracy and socioeconomic factors is supposed to decrease the fossil fuel consumption by an average of −0.2112 – 0.0366, ceteris paribus. The negative parameters for bureaucracy and the social-economic factors related to fossil fuel consumption reveal their decarbonizing effects where there is a higher level of bureaucracy and socioeconomic factors in the EU countries. This is in line with the EU environment policy based on Articles 11 and 191–193 of the Treaty on the Functioning of the European Union.

Next is the research output that fills in the necessary gaps regarding the role of bureaucracy and social-economic factors on the energy consumption mix and carbon emission literature of the European Union by unearthing whether bureaucracy and social-economic factors individually mitigate or dampen carbon emissions and/or if their interactions with energy consumption (oil, coal, and natural gas) enhance or alter their impact on carbon emissions. We extend the novel proposal of this study by comparing the degree of influence of bureaucracy and social-economic factors with carbon emissions. Spec [1] and [2] relate to the moderating role of bureaucracy and social-economic factors in oil consumption and the carbon emission nexus, Spec [3] and [4] relate to the moderating role of bureaucracy and social-economic factors in coal consumption and the carbon emission nexus, and Spec [5] and [6] relate to the moderating role of bureaucracy and social-economic factors in natural gas consumption and the carbon emission nexus. Their corresponding robustness checks using AMG technique are reflected in Table 8. The analysis and interpretations were recorded in turn.

3.1.1. Short-run and long-run estimates

The results of the short and long-run analysis of the carbon emissions function reported in Table 7 suggest that there is a positive impact due to GDP growth per capita in linear terms, whereas the squared terms suggest a negative impact on carbon emissions across all specifications [1 to 6], thereby validating the EKC hypothesis (U-inverted shape) in the presence of fossil fuel intensity under the auspice of "*grow now and clean later*" as postulated by Gill et al. (2017). In this context, the development in some EU countries (Eastern Europe) has increased environmental pollution in its early stages but reduced pollution in its later stages due to a massive embrace of environmental-friendly technologies and eco-friendly processes in multi-sectors (see the empirical verification of the EKC hypothesis in Alola and Ozturk, 2021; Alola and Donve, 2021). A similar finding is documented in the study by Kais and Sami (2016) for the case of the European and North Asian region. However, this research output is parallel to the findings of Boluk and Mert (2014) who posited that the EKC hypothesis does not hold in the selected 16 EU. The short and long-run coefficient of energy consumption (oil, coal, and natural gas consumption) is positive and a statistically significant predictor of carbon emissions at a 5% level of significance that varies between 12.9481 and 0.0471 across the 6 specifications respectively. This outcome is consistent with the work of Akadiri et al. (2019) and Bildirici and Bakirtas (2016) for BRICTS, indicating that energy consumption triggers environmental degradation and that an increase in energy

Table 3
Cross-section dependency test and Second generation unit test.

	CD test	CADF			CIPS		
		Level	first diff	result	level	first diff	result
lncem	27.40***	−1.397	−3.749***	I(1)	−0.523	−2.582**	I(1)
lngdp	75.20***	−1.663	−3.188***	I(1)	−0.442	−9.472***	I(1)
lngdpsq	75.08***	−1.681	−3.199***	I(1)	−0.355	−9.455**	I(1)
lnoil	11.76***	−2.114**	−3.652***	I(0)	−1.857**	−3.036***	I(0)
lncoal	41.17***	−2.205**	−3.993***	I(0)	−2.319**	−4.358***	I(0)
lngas	26.84***	−2.398**	−3.596***	I(0)	−3.306***	−6.783***	I(0)
lnbur	17.66***	−0.696	−3.896***	I(1)	−0.377	−4.355***	I(1)
lnoilbur	7.070***	−2.426***	−3.982***	I(0)	−1.677**	−4.564***	I(0)
lnsoc	48.55***	−2.108**	−3.267***	I(0)	−2.394***	−4.553***	I(0)
lnoilsoc	28.07***	−1791	−3.319***	I(1)	−1.018	−3.199***	I(1)
lncoalbur	32.29***	−1.760	−3.989***	I(1)	−1.184	−5.066***	I(1)
lncoalsoc	49.69***	−2.099**	−3.619***	I(1)	−3.388***	−5.222***	I(1)
lngasbur	26.88***	−2.374**	−3.612***	I(1)	−2.510**	−5.599***	I(1)
lngassoc	6.960***	1.620	3.326***	I(1)	−0.106	−5.686***	I(1)

Sources: Author's compilation Note: at 1%, 5% and 10% indicates significance level, decision based on ***p < 0.01, **p < 0.05, *p < 0.1

Table 4
Pesaran and Yamagata (2008) slope heterogeneity test.

variables	Spec1	Spec2	Spec3	Spec4	Spec5	Spec6
Delta tilde ($\widetilde{\triangle}$)	1.9436**	2.5210**	2.1365**	3.6880***	6.8610***	6.5970***
	0.0520	0.0120	0.0330	0.0000	0.0000	0.0000
Adjusted delta ($\widetilde{\triangle}_{Adj}$)	2.5244**	3.3130**	2.7560**	4.7620***	9.3200***	9.7910***
	0.0120	0.0010	0.0060	0.0000	0.0000	0.0000

Sources: Author's compilation. Note: at 1%, 5% and 10% indicates significance level, decision based on ***p < 0.01, **p < 0.05, *p < 0.1

Table 5
Error-correction panel cointegration test (Westerlund, 2007).

	Spec1		Spec2		Spec3		Spec4		Spec5		Spec6	
	Value	Robust P-value	Value	Robust P-value	value	Robust P-value	value	Robust P-value	value	Robust P-value	value	Robust P-value
G_t	−5.501***	0.000	−3.920***	0.000	−3.537***	0.038	−3.952***	0.002	−4.961***	0.002	−3.314***	0.005
G_a	−7.045***	0.000	−7.059***	0.435	−3.163***	0.035	−5.946***	0.070	−4.302***	0.018	−6.768***	0.006
P_t	−12.368***	0.013	−14.625***	0.003	−11.916***	0.000	−10.786***	0.000	−8.346***	0.048	−8.149***	0.003
P_a-	7.218***	0.035	−7.997***	0.080	−5.145***	0.013	−10.786***	0.024	−6.491	0.000	−6.382***	0.000

Note: at 1%, 5% and 10% indicates significance level, decision based on ***p < 0.01, **p < 0.05, *p < 0.1.
Sources: Author's compilation

Table 6
Augmented Mean Group estimator (Bond and Eberhardt, 2009; Eberhardt and Teal, 2010).

	Spec1		Spec2		Spec3	
	Coff	Prob	Coff	Prob	Coff	Prob
Constant	2.1657***	0.0000	1.4388***	0.0000	−1.3697***	0.0010
Lnsoc	−0.2112***	0.0000	−0.0736**	0.0034	−0.1370**	0.0460
Lnbur	−0.03660**	0.0.321	−0.0527***	0.0000	0.1522**	0.0100
Trend	No		No		No	
Wald x2	0.0001***		0.000***		0.000***	
Root mean squared error	0.00822		0.0157		0.0316	

Sources: author's compilation

consumption creates a picture of a "carbon curse" as stated by Friedrichs and Inderwildi (2013). Regarding the direct environmental impact of the bureaucracy and socioeconomic factors, their coefficients in the long and short-run are negative at a 5% level significance. The signs of the coefficients align with the outcomes of the recent literature that bureaucracy and socioeconomic factors are shock absorbers that have the strength to consolidate the government policies seeking to enhance the environmental quality in the EU (see Li Wang, 2012; Wawrzyniak and Doryn, 2020; and Salman et al., 2019 in the case of China).

Comparatively, the environmental impact of bureaucracy is found to be more pronounced across the specifications [1–6] than the socioeconomic factors. For instance, in spec 1 & 2, there is a 1% increase in bureaucracy which decreases the carbon emission in the selected EU nation by 40.5374%, and 38.7544% in the long-and short-run, on average, of the ceteris paribus. Meanwhile, there is a 1% increase in the socioeconomic factor which decreases the carbon emissions by 0.0471% and 0.0981% in the long-and short-run on average, ceteris paribus. This is expected as the bureaucratic system in Europe serve as a stimulus of economic and environmental performance (Ringquist, 1993; Povitkina, 2015).

Moving towards the contribution of this study to the body of knowledge, we consider the indirect/moderating or interaction terms which indicate whether bureaucracy and socioeconomic factors enhance or distort the fossil fuel-induced environmental impact across all model specifications [1–6], leading to the mitigation or aggravation of environmental degradation. In model specifications [1, 3 & 5] in Table 7, the coefficient estimates for the interaction terms *lnoilbur*, *lncoalbur* and *lngasbur* are similar, negative and significant. So far as the negative coefficients attached to the interaction terms attached to bureaucracy and fossil fuel consumption (oil, coal and natural gas) are concerned, their coefficient estimates reveal that the positive long-and short-run effects of fossil fuel consumption (oil, coal and natural gas) on carbon emission in European nations decreases as bureaucracy improves. Thus, the interaction terms imply that the positive environmental impact of fossil fuel consumption is conditional on the level of bureaucracy within the economy. The negative signs of the elasticity parameters attached to the interaction terms suggest that a higher level of bureaucracy is synonymous to an improvement in the environmental conditions that is likely to exhibit negative impacts on carbon emissions by reducing the environmental cost of GDP per capita triggered by energy consumption, reducing the positive impact of fossil fuels further. Accordingly, promoting a sound bureaucratic system alongside the GDP per capita could be a viable solution to the environmental challenges within the EU. Therefore, it is pertinent to promote bureaucracy and socioeconomic factors to simultaneously pursue GDP per capita and environmental welfare policies in tandem. This research output is consistent with the work of Wawrzyniak and Doryn (2020) in the case of emerging countries, with that of Salman et al. (2019) in the case of East-Asia, and with that of Abid (2017) in EU countries. However, it is on the contrary to the study by Saidi et al. (2020) in the case of the MENA Region.

Similarly, for model specifications [2, 4 & 6] in Table 7, the coefficient estimates of the interaction terms *lnoilsoc*, *lncoalsoc* and *lngassoc* are similar, negative and significant. However, the magnitude of these estimates (socioeconomic factors) is less than bureaucracy, hence the latter is more pronounced when it comes to exerting more influence on carbon emissions. So far as the negative coefficient attached to the interaction between the environmental impact of the socioeconomic factors and fossil fuel consumption (oil, coal and natural gas) is concerned, the coefficient estimate reveals that the positive long-and short-run effects of fossil fuel consumption (oil, coal and natural gas) on

Table 7
Dynamic common correlation effect by (Chudik and Pesaran (2015).

Variables	Spec1		Spec2		Spec3		Spec4		Spec5		Spec6	
	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob
short run												
Constant	8.0238***	0.0000	−13.229*	0.0810	6.6919	0.6490	−34.545**	0.0190	1.8853***	0.0000	0.0337	0.3870
L.cem	−0.7562***	0.0000	−1.0443***	0.0000	−0.5361***	0.0000	−0.5736***	0.0000	−0.3209**	0.0490	−0.4199***	0.0000
Δlngdp	5.5226**	0.0330	9.4292*	0.0780	2.8300*	0.0710	6.5311**	0.0150	1.2748**	0.0290	1.5709*	0.0750
Δlngdpsq	−0.2392**	0.0350	−0.3435*	0.0520	−0.1246*	0.0820	−0.2957**	0.0160	−5.4038**	0.0280	−0.1522**	0.0450
Δlnoil	12.9481**	0.0500	0.0471**	0.0240								
Δlncoal					1.4242**	0.0010	0.8156**	0.0020				
Δlngas									3.3274**	0.0060	0.2827**	0.0140
Δlnbur	−40.5374**	0.0200			−26.7907**	0.0060			−3.8887*	0.0860		
Δlnoilbur	−20.3350***	0.0010										
Δlnsoc			−0.4622*	0.0520			−0.3171**	0.0450			−0.0617	0.4270
Δlnoilsoc			−0.5354**	0.0220								
Δlncoalbur					−1.7482**	0.0310						
Δlncoalsoc							−0.6036**	0.0010				
Δlngasbur									−4.4645	0.2350		
Δlngassoc											−0.1160**	0.0270
Long-run												
Constant	1.2192*	0.0880	−7.4037*	0.0730	4.2226	0.6210	−21.279**	0.0160	0.6313	0.2470	0.0503	0.2920
lngdp	5.0614**	0.0020	5.5336***	0.0000	1.9043**	0.0050	4.0160***	0.0000	7.2435**	0.0330	12.1573***	0.0000
lngdpsq	−0.2232***	0.0000	−0.2066**	0.0080	−0.0856***	0.0000	−0.1818***	0.0000	−3.3559***	0.0000	−0.6798**	0.0010
lnoil	7.2712**	0.0040	0.0483**	0.0310								
lncoal					1.0024*	0.0880	0.4884**	0.0020				
lngas									1.9098**	0.0540	0.2509*	0.0930
lnbur	−38.7544**	0.0190			−18.1652*	0.0820			−2.8876**	0.0070		
lnoilbur	−11.4296**	0.0420										
lnsoc			−0.0981**	0.0600			0.1339**	0.0120				
lnoilsoc			−0.2526*	0.0740								
lncoalbur					−1.3190**	0.0360						
lncoalsoc							−0.3551**	0.0130				
lngasbur									−2.6585**	0.0240		
lngassoc											−0.0633**	0.0070
Obsv	700		700		700		700		700		700	
No of groups (N)	25		25		25		25		25		25	
Time(T)	28		28		28		28		28		28	

Sources: Author's compilation. Note: at 1%, 5% and 10% indicates significance level, decision based on ***p < 0.01, **p < 0.05, *p < 0.1

Table 8
Robust test: Augmented Mean Group estimator (Bond and Eberhardt, 2009; Eberhardt and Teal, 2010).

	Spec1		Spec2		Spec3		Spec4		Spec5		Spec6	
	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob	Coff	Prob
Constant	11.9974	0.8300	16.4643	0.7890	12.843**	0.0050	−14.996**	0.0020	−85.5058	0.2068	−11.560	0.8740
Lngdp	2.3728**	0.0090	2.4183**	0.0410	21.7503**	0.0060	25.590**	0.0020	13.8309**	0.0026	1.1021**	0.0290
Lngdpsq	−0.1170*	0.0680	−0.1059**	0.0210	−0.8986**	0.0070	−1.0720**	0.0020	−0.5350**	0.0349	−0.0157*	0.0760
Lnoil	2.4339**	0.0290	0.1737**	0.0070								
Lncoal					1.1068**	0.0157	0.7170***	0.0000				
Lngas									0.9306*	0.0710	0.7634**	0.0160
Lnbur	−2.3327**	0.0930			−1.2724**	0.0260			−0.6908**	0.0030		
Lnoilbur	−3.0358**	0.0360										
Lnsoc			−1.0392**	0.0050			−0.7511**	0.0034			−0.8751**	0.0680
Lnoilsoc			0.7751**	0.0070								
lncoalbur					−1.2727***	0.0000						
lncoalsoc							−0.5178**	0.0018				
lngasbur									−1.0149*	0.0980		
lngassoc											−0.7037*	0.0720
Trend	No		No		No		No		No		No	
Wald x2	0.0000***		0.000***		0.000***		0.000***		0.000***		0.000***	
Root mean squared error	0.0119		0.0118		0.0146		0.0131		0.0179		0.0168	

Sources: Author's compilation. Note: at 1%, 5% and 10% indicates significance level, decision based on ***p < 0.01, **p < 0.05, *p < 0.1.

carbon emissions decreases when the socioeconomic factors improve. This is another significant contribution to the body of knowledge as it in tandem with the hypothesis suggesting that a higher level of socioeconomic factor is synonymous to an improvement in the environmental conditions, and that it is likely to exhibit a negative impact on carbon emissions by reducing the negative externalities from the environmental costs aggravated by energy consumption. These findings support the extant repositories by Bel and Rosell (2017) that education and occupation do not increase the carbon emissions in Barcelona city, Spain, by proposing that the socioeconomic factor not only supports multi-dimensional economic activities but also improves the environmental conditions vis-à-vis reducing the positive impact of energy consumption on carbon emissions. On the contrary to this finding, Bello et al. (2021) argued that education increases environmental pollution significantly in the case of sub-Saharan Africa. Vita et al. (2020) and Ivanova et al. (2017) found there to be an increase in environmental degradation when the socioeconomic factor increases.

3.2. Robustness check

Estimations in the panel data analysis can lead to several econometrics issues which, when not identified, can lead to misleading results. Hence, it is important to check the robustness of the DCCE estimates in Table 7. We implemented the relative novel technique AMG developed by Bond and Eberhardt (2009) as was carefully applied by Eberhardt and Teal (2010). The AMG is efficient, unbiased, and robust for different combinations of time series, cross-section, time dimension with non-stationary series and it can account for the presence of cross-section dependence and country-specific heterogeneity in panel data (Eberhardt and Teal, 2010). The research output is presented in Table 8. Targeting the key variables of the interaction terms, both estimators of DCCE and AMG yielded complementary results for the signs but with slit discrepancies, especially for the magnitude of the coefficients. The results presented in this section further revalidate the research output highlighted earlier as thus: i.) Growth-induced EKC reconfirmed ii.) The result also affirms the positive and negative environmental impact of fossil fuel consumption, bureaucracy, and socioeconomic factors on carbon emissions. As expected, the magnitude of bureaucracy is greater than the socioeconomic factors across the model specification [1–6] iii.) The parameter estimates for the interaction terms also show as negative and significant across the model specification [1–6].

Interestingly, this empirical adventure extends the debates in three strands areas in energy economics. The first strand shows that fossil fuel consumption has a deteriorating impact on environmental performance due to its positive effect on carbon emissions (Bekun et al., 2019; Dogan and Seker, 2016; Al-mulali, 2011; Bildirici and Bakirtas, 2016; Saboori and Sulaiman, 2013). It can provide a picture of how fossil fuel consumption moderates the relationship between national income and carbon emissions under the auspices of the EKC hypothesis. The second strand highlights how the direct effect of bureaucracy and the socioeconomic factors exert a negative impact on the influence of environmental pollution/degradation (Povitkina, 2015; Ringquist, 1993). The overall consensus among scholars is that the direct effect of bureaucracy and the socioeconomic factors promotes environmental quality but the degree or magnitude of influence is more pronounced in a sound bureaucratic system. The third strand posits that there are indirect effects due to bureaucracy and the socioeconomic factor on the environment via fossil fuel consumption within the EU.

Surprisingly, there are no empirical entries to explain the juxtaposing relationship of the indirect/moderating roles of bureaucracy and the socioeconomic on environmental quality. In this study, we show how bureaucracy and the socioeconomic factors can reverse the degrading environmental impact of fossil fuel consumption by moderating the relationship between GDP per capita fossil fuel consumption and carbon emissions, such that bureaucracy and the socioeconomic factors are more likely to have a mitigating effect on environmental quality due to ameliorating the effect of fossil fuel-induced environmental impacts in EU countries. The findings are consistent with the work of Povitkina (2015) and Ringquist (1993) who provide support for the quality of the bureaucratic system and the socioeconomic factors effect hypothesis which has significantly been used to explain the de-carbonation fossil curse in many nations.

3.2.1. Causality result

Additional test i.e the D-H causality analysis is carried out with the results provided in Table 9. On the causal relationship between GDP per capita and carbon emissions, the statistical significance of the W-stat and Zbar-Stat favors the unidirectional causal flows from real gdp and square rgdp to carbon emissions. This is in line with the regression output and a potential explanation for this outcome is that expanding the economic development in the EU nations would promote carbon emissions. Oil consumption has a bidirectional causality with carbon emissions whereas coal and natural gas have a unidirectional causality with carbon emissions. The results suggest that fossil fuels contribute strongly to the environmental degradation within the EU nations. Similarly, there is a unidirectional flow between the interaction terms and carbon emissions with the exception of the interaction term between coal consumption and bureaucracy that reports a bidirectional causality. This causal relationship aligns with the extant studies by Akadiri et al. (2019), Al-mulali (2011), and Saboori and Sulaiman (2013). Bureaucracy and socioeconomic factors create a mitigation path in relation to environmental quality. In sum, the regression output and the Granger causality are reported in the schematic diagrams shown in Fig. 2.

Table 9
DH Granger causality result.

Argument	W-stat	Zbar-Stat	p-value	Direction causality
lngdp→lncem	3.3116	8.1727	0.0100	*lngdp→lncem*
lncem→lngdp	2.6430	5.8090	0.2700	
lngdpsq→lncem	3.3041	8.1472	0.0100	*lngdpsq→lncem*
lncem→lngdpsq	2.6601	5.8692	0.2500	
lnoil→lncem	5.1012	7.7539	0.0300	*lnoil↔lncem*
lncem→lnoil	3.0915	7.3944	0.0200	
lncoal→lncem	4.0496	5.1240	0.0700	*lncoal→lncem*
lncem→lncoal	1.3808	1.3463	0.7200	
lngas→lncem	4.4261	6.0652	0.0500	*lngas→lncem*
lncem→lngas	2.9834	2.4585	0.4700	
lnbur→lncem	7.3200	7.1340	0.0000	*lnbur↔lncem*
lncem→lnbur	6.4200	6.5340	0.0000	
lnoilbur→lncem	3.1189	7.4913	0.0100	*lnoilbur→lncem*
lncem→lnoilbur	1.4762	1.6836	0.6301	
lnsoc→lncem	3.6488	3.2939	0.0520	*lnsoc→lncem*
lncem→lnsoc	1.5009	1.7709	0.6800	
lnoilsoc→lncem	3.3853	3.3621	0.0700	*lnoilsoc→lncem*
lncem→lnoilsoc	1.9141	3.2317	0.3600	
lncoalbur→lncem	4.9702	5.8257	0.0630	*lncoalbur↔lncem*
lncem→lncoalbur	1.5164	2.9702	6.9656	
lncoalsoc→lncem	3.8618	5.1546	0.0530	*lncoalsoc→lncem*
lncem→lncoalsoc	2.2250	4.3311	0.1800	
lngasbur→lncem	3.9451	4.8627	0.0700	*lngasbur→lncem*
lncem→lngasbur	1.9794	3.4627	0.3100	
lngassoc→lncem	3.6718	5.3751	0.0400	*lngassoc→lncem*
lncem→lngassoc	2.1040	3.9049	0.2000	

Note: at 1%, 5% and 10% indicates significance level, decision based on ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

4. Summary and policy implications

In recent decades, European nations have continued to witness a continuous growth. However, this growth has not been immune to the increase in climatic change emanating from high demand of human and economic activities. These nations have not been able to maintain the welfare of their particular environmental qualities while growing economically. As a result, the macroeconomic elements which can address the worsening environment issues in these countries are relevant to these economies. It is against this backdrop that this study investigates the dynamic relationship between bureaucracy, socioeconomic factors, fossil fuel consumption and environmental quality in the selected 25-EU nations from 1990 to 2017. After the preliminary descriptive statistics and correlation matrix tests were carried out, the econometric protocols implemented are as follows. The second-generation test was implemented following the example of Pesaran (2004) and Pesaran and Yamagata (2008) to test for CD and slope heterogeneity problems in the data. Accordingly, the Pesaran (2007) CIPS and Pesaran (2003) unit root tests were used to check the stationarity properties of the variables. The second-generation panel test was assessed using the Westerlund (2007) approach. To assess the robustness of the long-run estimates and also to account for the country-specific coefficients and heterogeneity, the short- and long-run

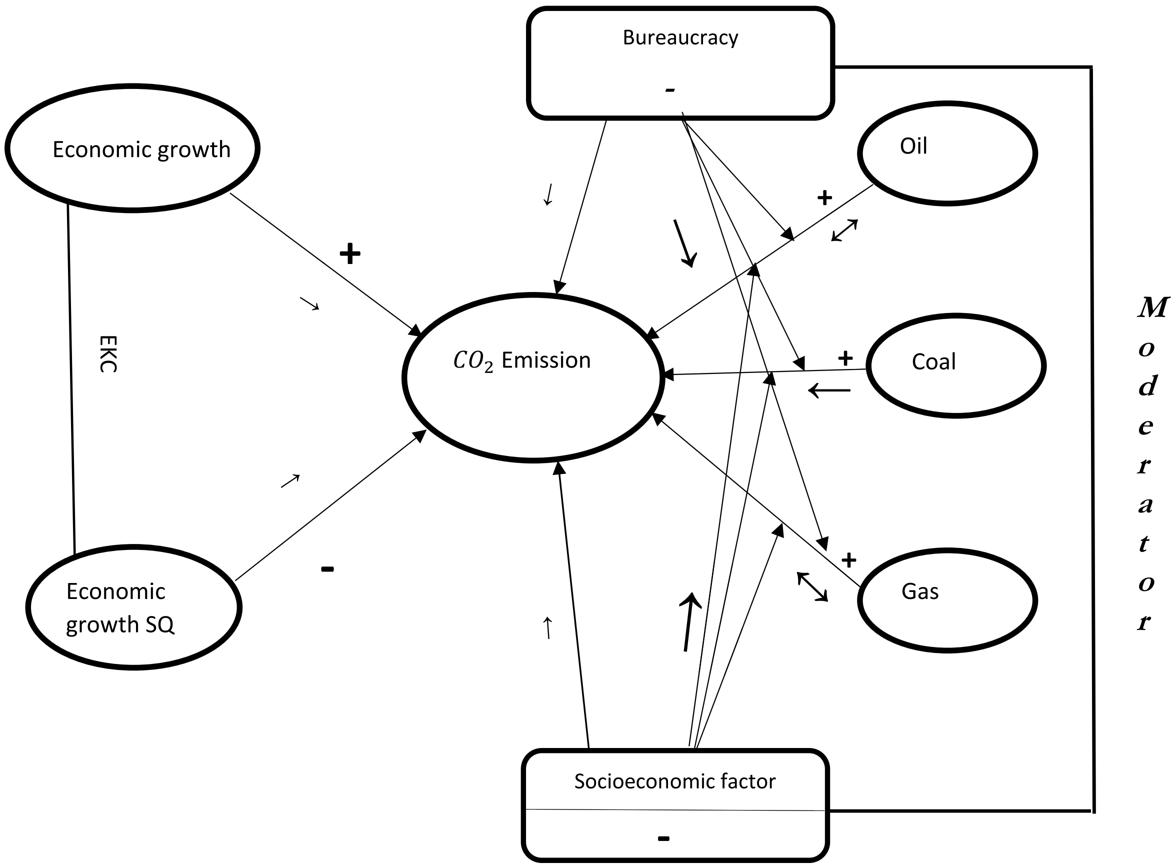

Fig. 2. Schematic view of research output.
Sources: author's design.

coefficients were determined using the DCCE method established by Chudik and Pesaran (2015) and the AMG estimator of Eberhardt and Teal (2010). The direction of the causality test was implanted using the example of Dumitrescu-Hurlin.

In terms of the bigger picture, this study covers two key research issues including i) whether bureaucracy, socioeconomic factors and fossil fuel consumption exert a significant impact on environmental quality and ii) whether the efficient implementation of bureaucracy and improved socioeconomic factors enhances or distorts the environmental impact of fossil fuel consumption. In particular, the empirical evidence unearthed the following: (1) fossil fuel consumption has a dampening impact on environmental performance due to its positive effect on carbon emissions; (2) that the direct effect of bureaucracy and socioeconomic factors promote environmental quality but the degree or magnitude of influence is significantly different according to the bureaucratic system and socioeconomic factor, and (3) the moderating or indirect impact of bureaucracy and socioeconomic factors on the environment via fossil fuel consumption promotes environmental quality, and it is significantly different across the model specifications; (4.) there are unidirectional causal relationships from GDP per capita, coal, bureaucracy and socioeconomic factors to carbon emissions, while a bi-direction relationship exist between oil, gas, and emissions.

4.1. Policy

The recommendation of this research output is highlighted by drawing on inference from the meaning of EKC in EU-25, substantiating that the member states need more in mitigating environmental degradation through making environmental wealth a key pathway toward attaining economic sustainability. The negative signs of the elasticity parameters attached to the interaction terms suggest that a higher level of bureaucracy is synonymous with an improvement in the environmental conditions that is likely to reduce the environmental costs of GDP per capita triggered by energy consumption. The policy option in this regard should be that the EU governing body has to reinforce a policy that further assess the feasibility of the scope of action relating to domestic fiscal policies considering the geographical issues associated with national planning, land use, quantitative water resource management, the choice of energy sources, and the structure of the energy supply in the respective member nations. There is also the need to encourage policymakers within the bloc to relax some of the existing obstacles to the installation of alternative (i.e wind and solar) energy infrastructures. Particularly, this includes cutting down on the duration of the permitting processes, providing alternative dispute resolutions for opposing members, promoting the alignment of country-specific goals to climate agreements, and reducing the volume of environmental regulations and higher bureaucratic expertise to hasten the progress towards renewable energy. The EU can achieve a higher volume of carbon net sink by 2030 by reinforcing the bureaucratic structure such as strengthening the European Scientific Advisory Board on Climate Change toward providing independent scientific guidelines and reporting on the EU climate initiatives.

CRediT authorship contribution statement

Andrew Adewale Alola: Writing – review & editing, Conceptualization, Formal analysis, Supervision, Validation, Visualization. **Kingsley Ikechukwu Okere:** Investigation, Methodology. **Obumneke Bob Muoneke:** Writing – original draft. **Glory Chiyoru Dike:** Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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