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Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability in the EU-28: Evidence from a GMM panel-VAR

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A B S T R A C T

Despite the high commitments of the European Union (EU) member countries toward achieving the sustainable development goals (SDGs), on average, the region has reportedly under performed in the area of ensuring sustainable production and consumption. This paper uses the Generalized Method of Moments (GMM) estimation of panel vector autoregressive (PVAR) with impulse response functions (IMFs) to assess the effects of domestic material consumption, renewable energy, financial development, and greenhouse gas emissions on environmental quality in the EU-28 countries based on the panel data for the period 2000:Q1–2017:Q4. The empirical results reveal that the shocks to domestic material consumption, renewable energy, economic growth, financial development, and greenhouse gas emissions affect the drives towards a sustainable environment. Particularly, the shocks to renewable energy and financial development improve environmental quality, while the shocks to domestic material consumption and greenhouse gas emission deteriorate environment quality. The shock to economic growth improves environmental quality up to the 4th horizon after which it begins to deteriorate environment quality. Furthermore, the panel causality results indicate bidirectional causality between greenhouse gas emissions and the rest of the variables except renewable energy, which is unidirectional. The causality between economic growth and renewable energy, economic growth and financial development, and financial development and renewable energy has a feedback effect while a unidirectional causality flows from economic growth to domestic material consumption. These findings have implications for sustainable production and consumption.

1. Introduction

Given the coordinating mechanism of the United Nations Environmental Programme (UNEP), there is a global target of achieving sustainable management and efficient utilization of natural resources by 2030. Among the essence of achieving a sustainable target is to have a sustainable economic performance without compromising the quality of the environmental systems [1,2]. In general, the supply chain of production and consumption of the economy which includes the production of primary raw materials, its subsequent development/manufacturing into a product, and the eventual disposal of waste material, are all environmentally linked [3,4]. Consequently, in the absence of an efficient production policy, a large primary production sector for both domestic use and export expectedly yields a huge domestic material consumption (DMCC). In most advanced and some emerging economies (such as the United States, some European Union States, and China), the outsourcing of the industrial process especially of high material intensity to the developing or undeveloped economies is fast becoming a prevailing effective economic and environmental policy. Considering that the chain line of industrial production accounts for a significant proportion of environmental degradation in

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Europe, the European Union (EU) identifies the need to expand Sustainable Development Goal (SDG) 12. In specific, the European Commission (EC) adopted the Sustainable Consumption and Production, and Sustainable Industrial Policy (SCP/SIP) Action Plan that supports the European sustainable product policies [5].

In addition to eco-design of Energy-Related Products (ErP) and Energy Label policies, the EU specifically adopted other environmental and sustainable product policies that include EU Eco-label, Green Public Procurement, and other clean energy technologies [6]. Specifically, the intensity of greenhouse gas (GHG) emissions especially due to power generation across the EU member countries has since continued to decline due to effective implementation of the energy and environmental policies. The European Economic Area (EEA) opined that the EU policies that include the Renewable Energy Directive and EU Emissions Trading Scheme are responsible for the significant decline in EU's GHG emissions intensity (from electricity generation) from 510gCO2e/kWh in 1990 to 281gCO2e/kWh in 2018 (European Economic Area (EEA) 2020a). In spite of the aforementioned success, the EU is at the risk of failing to meet its 2020 and 2030 energy efficiency targets because the final energy consumption among the EU member states largely remained stable between 2018 and 2019 [7]. Although the EEA acknowledges a significant and consecutive decline in primary energy consumption in 2019, the stability of the final energy consumption (by end consumers) remained the highest and above the 2010 level. Thus, the GHG emission in the EU especially from electricity generation (as indicated in Appendix A) and the transportation sector has remained a serious challenge for the member states.

Considering the aforementioned motivation, it is vital to further expand the investigation of the environmental sustainability outlook for the EU member countries especially from the aspect of material consumption. This is important because in addition to the commercial significance of production and/or consumption aspects, mostly all parts of human endeavours are aligned with the socio-economic and environmental activity aspects. Thus, the current study undertakes the task of examining the determinants of environmental sustainability via - GHG emissions. Put differently, the study investigates the effects of domestic material consumption, renewable energy, financial development, and greenhouse gas emissions on environmental sustainability in the EU-28 member countries. Therefore, this study contributes to the literature in several ways: First, as against carbon dioxide (CO_2) emission extensively used in the literature, greenhouse gas emission is employed as a proxy for environmental sustainability because it encapsulates gases from human activities that include carbon dioxide, methane, nitrous oxide, and industrial gases, as well as water vapour and ozone [8]. Second, the study unravels the role of domestic material consumption in attaining the EU's sustainable production and consumption and environmental sustainability targets. In addition, the role of renewable energy consumption amidst the outline targets is considered an important objective in this study. Moreover, because of the EU's green deal investment plan and other adopted carbon financing mechanisms, this study captures the role of financial development and economic growth in the EU's environmental sustainability target, and further considers the important role of greenhouse gas emissions (own shock) in the achieving the EU's environmental sustainability target. Third, on the methodological basis, this study employs the Generalized Method of Moment (GMM) estimation of Panel Vector Autoregressive (PVAR) Model with Impulse Response Functions (IRFs) to demonstrate the significance of the study. To this end, the study offers renewed policy guides especially to the EU's energy efficiency target for 2030 and carbon neutrality target by 2050.

The remaining sections aside from the introduction are as follow. Section 2 discusses the existing studies on the topic. Section 3 gives detailed data and methodology adopted for this current study. Section 4 presents results and discussion of findings, while the last section 5 concludes with attendant policy suggestions, especially the sampled EU member countries.

2. Extant studies: a synopsis

In the literature, several factors have been established as the drivers of environmental sustainability. Although the DMCC has been examined from different perspectives, mostly employed as the environmental variable (See Refs. [4,9], there seems to be limited studies that have looked at the DMCC from the perspective of driving environmental sustainability vis-à-vis the GHG emissions. Among the rare studies that have examined the determinants of environmental pollution from the perspective of DMCC are [3,4]. In the study [3], examined the role of aggregate domestic consumption spending per capita (ADCSP) in the profile of carbon dioxide (CO_2) emission in South Africa. In specific, the study revealed that a 1% increase in ADCSP is responsible for 0.31% and 0.22% increase in CO_2 emission in the long run and short run respectively. In addition, the study of [3] infer from the non-linear Autoregressive Distributed Lag (NARDL) that a positive shock in ADCSP strongly triggers CO_2 emission in the long run more than in the short run. Similarly [4], found that DMCC worsens the environmental quality of the panel of EU member countries in the long- and short-run. In addition to the DMCC [4], found that real income is also detrimental to the environment while alternative energy source is considered to appear in mitigating GHG emissions.

Concerning the role of renewable energy utilization in environmental sustainability, this perspective has been intensively presented for varying cases of the EU and member states [10], the developed nations such as the G-7 [11–14], a combination of developed and developing countries such as the Organization for Economic Corporation and Development (OECD) [15–17], and other cases [18]. In specific [19,20], both examined the determinants of CO_2 emissions in the EU from the perspective of renewable energy use among other potential factors. While both studies found that, the utilization of renewable energy in the panel of EU countries yields a carbon mitigating effect, the study of [19] was performed in the framework of the Environmental Kuznets Curve (EKC). Additionally [21], employed the NARDL approach in explaining the asymmetric role of clean energy utilization in carbon emission for the period of 1975–2018 for Pakistan. The study found that positive and negative shocks in alternative energy sources (including cleaner, nuclear, and combustible waste energy sources) has different effect on carbon emission in Pakistan.

Moreover [22,23], are some of the extant studies that explored the role of financial development in environmental sustainability for the case of Pakistan and the panel of African countries respectively. In specific [22], employed the Bank- and Stock market-based financial development indicators and found that the indicators contribute to environmental degradation in Pakistan. However [23], employed the GMM approach to reveal the determinants of environmental degradation for the panel of 26 African states over the period 1985–2011. Considering the influence of the political regime [23], found that financial development stands the chance of profiting environmental quality in the examined countries. In addition [24], explored the EKC approach to examine the influence of financial development among other factors on CO_2 emissions in the United Arab Emirates (UAE) for the period of 1975–2011. Interestingly, the study found that there is a significant and inverted U-shaped relationship between financial development and carbon emissions in the examined country [13,25]. are among several other studies that explore the nexus between financial development and environmental sustainability.

The discussion of the extant studies as illustrated above clearly

Table 1
Variable, measurement, and source.

Variable	Measurement	Source
Greenhouse Gas Emissions (GHG)	The total major greenhouse gases and emissions from man-made measured in thousands of tonnes of CO_2 equivalent)	World Development Indicators (WDI) updated by the European Commission (EC) statistics (Eurostat, 2020).
Economic Growth (GDP)	Gross Domestic Product (GDP) per capita (Constant 2010 USD)	World Development Indicators (WDI)
Renewable Energy (RENE)	The contribution of renewable energy to the overall primary energy supply, and is measured in thousand tones of oil equivalent	Organization for Economic Co-operation and Development (OECD)
Domestic Material Consumption (DMCC)	The amount of material used domestically in an economy and is measured in thousand tonnes.	Organization for Economic Co-operation and Development (OECD)
Financial Development Index (FDV)	Index of the financial institution and financial market measured based on depth, access, and efficiency.	International Monetary Fund (IMF)

Source: Authors' computation

affirms the link between environmental sustainability and domestic material consumption, renewable energy utilization, financial development, and economic growth. Additionally, as displayed in appendix B, only limited studies have illustrated the determinants of domestic material consumption, especially for a panel of European Union states. Moreover, there is little or no evidence available on the role of greenhouse gas emission (own shock) in influencing environmental sustainability. Thus, in a different approach from the previous studies, the current assessment potentially deepens the study of domestic material consumption in the EU by examining its link with economic growth, financial development, renewable energy consumption, and greenhouse gas emission on environmental sustainability.

3. Data and methodology

The current section presents the description of the examined variables alongside the application of the essential empirical methods.

3.1. Data

In this paper, we make use of the panel data spanning from 2000M01–2017M12. The variables in the panel VAR include the log difference of Greenhouse Gas Emissions (GHG), real GDP per capita (GDP), renewable energy as the contribution of renewables to the total primary energy supply, measured in thousand tonnes of oil equivalent (RENE), Domestic Material Consumption (DMCC), and financial development index (FDV). We express all the variables in their natural logarithms to control for heteroscedasticity.[1] These variables and their measurements and sources are presented in Table 1.

3.2. GMM estimation of panel VAR model

The estimation techniques for this study entail a series of essential procedures which are expectedly performed in a specialized order based on the natural logarithm growth rate.[2] In Fig. 1, the step-by-step procedures are illustrated for clarity.

In this study, to control for fixed effects in the cross-country effects of renewable energy, economic growth, domestic material consumption, financial development, and GHG emissions in the 28 European Union member countries (EU-28), we apply a flexible framework of Panel Vector Autoregressive (PVAR) model, which allows all the variables to be treated as endogenous. This method has been applied extensively in the literature to examine policy transmissions and relationships among various economic variables. The PVAR model, therefore, has an enviable advantage of standard VAR and Panel data modelling techniques. For example, as a model belonging to a VAR family, the approach can help to deal with endogeneity problems while as a panel; it can also help in improving estimation efficiency [26,65]. Furthermore, Panel VAR helps to assess the interactions among the variables of interest through impulse response functions. Lastly, it improves the efficiency of panel Granger causality analysis within the Panel VAR model, which helps to identify the direction of the causal nexus between the variables.

The conventional Panel VAR model with fixed effects is given by the following equation:

$$Y_{i,t} = \beta_i + \sum_{j=1}^{m} \theta_j Y_{i,t-j} + \mu_{i,t} \tag{1}$$

where $Y_{i,t}$ is $N \times 1$ a vector of the dependent variables, θ_j denotes $N \times N$ matrix of the autoregressive coefficients, β_i which is a vector of country-fixed effects that mainly controls for unobserved individual heterogeneity while $\mu_{i,t}$ is a vector of error terms. The $(i = 1, ..., N)$ simply means the country while $(t = 1, ..., T)$ is the time period.

Theoretically, the VAR model of a 5-dimension such as a type being employed in the current study often suffers a loss in degree of freedom. However, by applying a panel data technique which increases the number of observations, it can help, therefore, to mitigate the consequence of loss in degrees of freedom, and considerably generates a large confidence interval for the Impulse Response Functions (IMFs). As shown by Ref. [27] and recently echoed in a study by Ref. [28]a), the coefficients of VAR are not reliable in making meaningful policy decisions; hence, the IRFs are very important and most reliable.

To estimate our model, we follow [29,30] who proposed estimators via the first difference transformation of the standard VAR model in Equation (1) on the basis of the generalized method of moments (GMM). This is to enable such estimates of the VAR to be consistent as recently revealed by Ref [65]. Given that in a dynamic equation, error terms are serially correlated [31], argue that the first difference transformation of variables may not still achieve consistent estimates, hence they proposed what is popularly known as the forward orthogonal deviation in the literature. In this proposal, the mean of future observation in the sample is taken from each observation. Hence, the variables transformed and the error terms are given as:

$$Y^*_{it-s} = w_t[Y_{it-s} - (Y_{it-s+1} + ... + Y_{iT-s}) / (T-t)] \quad (s = 0, 1, ..., p) \tag{2}$$

[1] Theoretically and empirically, converting the series into their natural logarithms help removing nonlinear functional form and ensure stability of the variance. Since the proof is outside the scope of our paper, we have referred interesting readers to check [61,62].

[2] The growth of variables as shown in Refs. [63,64]a,b) makes the VAR model robust and stable if the variables are not stationary.

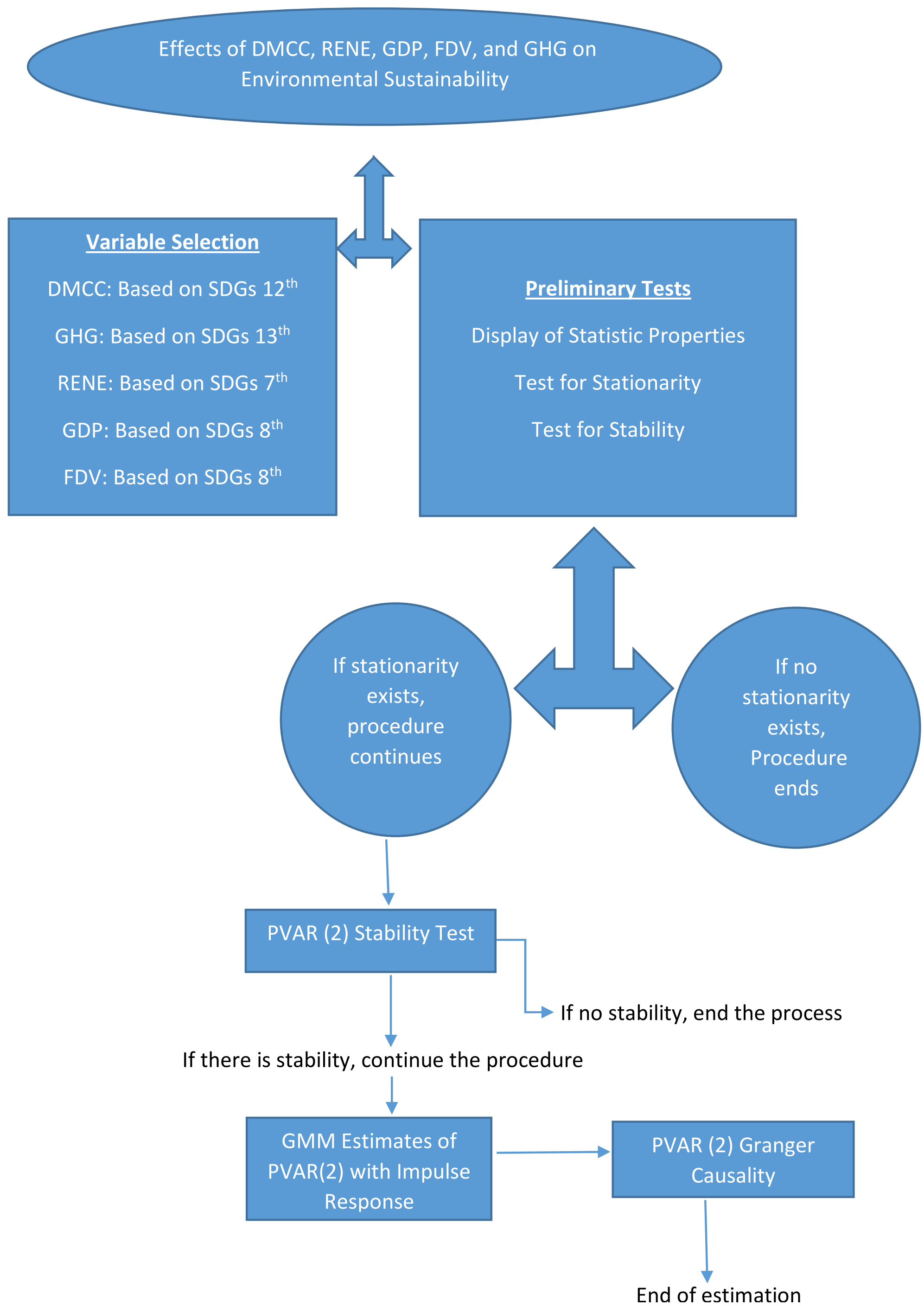


Fig. 1. The flow chart of the estimation procedure.

$$\mu_{it}^{*} = w_t[\mu_{it} - (\mu_{it+1} + ..., + \mu_{iT})/(T-t)] \ \text{with} w_t^2 = (T-t)\Big/(T-t+1) \tag{3}$$

Where Y_{it}^{*} indicates the transformed vector of the dependent variables, μ_{it}^{*} is the transformed error term, which is independently and identically distributed (i.i.d.). T is the year period for a given country (T = 2000, 2001, …, 2017), i denotes countries, s represents the lag order of the Panel VAR and w_t denotes a non-singular weighting matrix. As noted by Ref. [32], this transformation has the advantage of inheriting the properties of the original error term, i.e. if the original error term is homoscedastic and serially uncorrelated, the transformed term would also be homoscedastic and serially uncorrelated.

To achieve the objective of this study, Equation (1) is estimated via the GMM technique and the forward orthogonal deviation recently used by Ref [65]. As earlier stated, the estimates of the VAR are not reliable hence we construct the impulse response functions (IMFs) to examine the nexus between renewable energy, economic growth, domestic material consumption, financial development, and greenhouse gas emissions in the EU-28.

3.3. Panel VAR Granger causality analysis

We explore the panel VAR Granger causality to test the causal relationship between the variables since the panel series we apply in this study are all integrated of order one i.e. I(1) and cointegrated. The causality analysis would help policymakers to design and implement environmental policies that curtail the environmental effects of economic growth in the EU-28 countries. The framework for the panel VAR Granger causality in line with [33] is given as:

$$X_{i,t} = \alpha_0 + \sum_{j=1}^{m} \alpha_{1,j} Y_{i,t-j} + \sum_{j=1}^{m} \alpha_{2,j} Y_{i,t-j} + \tau_i + u_{i,t} \tag{4}$$

$$Y_{i,t} = \delta_0 + \sum_{j=1}^{m} \delta_{1,j} X_{i,t-j} + \sum_{j=1}^{m} \delta_{2,j} X_{i,t-j} + \eta_i + \nu_{i,t} \tag{5}$$

where m is the lag length, $u_{i,t}$ and $\nu_{i,t}$ are the error term, which are assumed to be white noise. τ_i and η_i are invariably individual fixed effects. i and t denote the given country and time period as already defined. The difference of variable Y is said to have predictive power for the difference of variable X if the lagged variable Y provides information regarding variable X. On the other hand, if the reverse is the case, we conclude that the difference of variables X has predictive power for variable Y. The null hypothesis for the Panel VAR causality is given as follows:

$$H_0 : \alpha_{2,1} = \alpha_{2,2} = \dots\dots\dots = \alpha_{2,m} = 0 \tag{6}$$

and

$$H_0 : \delta_{2,1} = \delta_{2,2} = \dots\dots\dots = \delta_{2,m} = 0 \tag{7}$$

The test uses χ^2-stat (chi-square) to test whether the null hypothesis that the excluded variable does not Granger-cause equation variable hold or not.

4. Results and discussion of findings

Table 2 displays the descriptive statistics based on log levels and growth rates for the EU-28 countries. As shown in the Table, the mean of GHG is the largest in the log level, followed by the mean of GDP while FDV is the smallest and - is negative. For the case of growth rate, we find that the highest mean in renewable energy consumption. The mean of DMCC is negative while the mean of GHG is the smallest in terms of the absolute value. Furthermore, the standard deviations of the variables in both log level and growth rate are very low, suggesting that the variables are not volatile. The skewness of the log level is negative, which implies that the variables are all negatively skewed while in the case of growth rate the skewness is positive for all the variables except GHG. In addition, the kurtosis of the variables suggests positive and excess kurtosis. Consequently, the Jarque-Bera statistics are large, which implies that the null hypothesis of the normal distribution of the variables is rejected. Generally, the transformation of the series by taking the natural logarithmic is significant in stabilizing the variance and removing the nonlinear functional form, thus improving the goodness-of-fit.

Table 3 presents the correlation matrix of the variables. As shown in this Table, GHG has a positive and significant correlation with all the variables except DMCC, which is negative and significant. The correlation between GDP and RENE is negative and significant while with DMCC and FDV, the correlation is positive and statistically significant. Furthermore, we find a positive and significant correlation between RENE and DMCC while RENE negatively correlates with FDV with evidence of significance. Finally, DMCC positively correlates with FDV. The correlation is statistically significant; easily passes a test of 1% level of significance.

Table 4 reveals the results of the CIPS panel unit root test, which captures potential heterogeneity and cross-sectional dependence properties inherent among panel countries. Results show that the variables are non-stationary at levels, except FDV under constant and trend at ($p < 0.10$) significance level i.e. weak stationarity. However, the remaining variables are significant at ($p < 0.01$), suggesting stationary at their first differences. Thus, we conclude that the variables under investigation are stationary at first order (both at constant and constant and trend).

Table 5 presents the PVAR (2) process stability results. PVAR stability results reveal that the modulus (M) and the eigenvalues (E), that is, the absolute value of the root of the (PVAR process feature) equation are less than one ($M < 1$) and ($E < 1$). The stability result ensures the stationarity of the panel variables under investigation and the panel vector autoregressive (PVAR) system. Thus, having confirmed the stability of the PVAR model, we proceed with the PVAR model estimation. The PVAR(2) estimated via GMM is performed by removing the fixed effects from the panel series via first-order differencing of the panel series as suggested in Ref. [31]. The estimated coefficients of the PVAR(2) model are reported in Table 6. It is paramount to state here that the interpretation of the estimated coefficients derived from the PVAR(2) model may not be entirely useful or relevant due to the theoretical feature of the VAR model (see [28,65]).

Table 6 shows that greenhouse gas emissions react positively to renewable energy consumption and financial development, and react negatively to a change in gross domestic product and domestic material consumption. Moreover, changes in gross domestic product, renewable energy consumption, and financial development react positively to greenhouse gas emissions, while a shock to domestic material consumption reacts negatively to greenhouse gas emissions after two months. On the other hand, the result shows that there is the possibility of an asymmetric relationship between the variables of interest over a period of time. For example, we observe that greenhouse gas emissions reduce renewable energy (negative impact) in the first lag, while increasing (positive impact) demand for renewable energy consumption in the second lag. In addition, we found that renewable energy consumption due to its huge cost of capital reduces economic growth, while greenhouse gas emissions in terms of the amount of energy consumed contribute to economic growth after the first lag.

As discussed earlier, more meaningful economic interpretations and policy-guided results are provided with the empirical results generated from the impulse response functions (IRFs) and panel causality analysis presented in Figs. 1–4 and Table 7. Starting from Fig. 1, the results reveal the response of economic growth; renewable energy consumption, domestic material consumption, and financial development to shocks in greenhouse gas emissions, with the 95% confidence interval. For better analysis, we compute the responses of the variables for a period of 8 months, which we are of the opinion that it is sufficient to evaluate the full impacts of policy response. The IRF in Fig. 1 divulges that economic growth and financial development react positively and significantly to shocks in greenhouse gas emissions. We also find that own shock is positive and statistically significant over the horizons. This result indicates that an increase in greenhouse gas emissions as a by-product of energy consumption is traceable to an increase in own variable, financial development as well as economic growth. As more energy is demanded for production and consumption purposes, economic activities increase and this situation would rob-off on financial services. Increases in the level of economic, financial and

Table 2
Descriptive statistics.

Variable	Obs.	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	JB	*p*-value
Panel A: Log levels										
GHG	6048	11.26589	11.22585	14.13230	7.293150	1.378050	−0.215201	2.679446	72.57630	0.000000
GDP	6048	10.14603	10.23880	11.90100	7.890950	0.690293	−0.286529	2.507480	143.8850	0.000000
RENE	6048	2.356385	2.496865	4.655440	−3.075260	1.055204	−1.511437	6.945436	6225.465	0.000000
DMCC	6048	2.699834	2.746705	3.645030	0.551878	0.465043	−1.989097	9.679396	15230.97	0.000000
FDV	6048	−0.634872	−0.479142	0.011996	−2.336110	0.426951	−0.939347	3.093322	891.6266	0.000000
Panel B: Growth rate										
GHG	6020	0.000154	0.000000	0.628322	−0.710455	0.040062	−1.883029	97.52020	2244520.	0.000000
GDP	6020	0.000703	0.001468	0.418967	−0.282586	0.023671	2.968938	91.01601	1952004	0.000000
RENE	6020	0.001486	0.003116	0.715418	−0.318850	0.039120	4.187994	101.8739	2469758	0.000000
DMCC	6020	−0.000212	−2.74E-05	0.265283	−0.130387	0.016007	2.409052	61.61450	867601.0	0.000000
FDV	6020	0.000317	0.000299	0.430328	−0.221170	0.017701	3.816156	128.8508	3987417	0.000000

Table 3
Correlation matrix.

Variable	GHG	GDP	RENE	DMCC	FDV
GHG	1.000000				
	———				
GDP	0.172317	1.000000			
	0.0000	———			
RENE	0.064198	−0.169014	1.000000		
	0.0000	0.0000	———		
DMCC	−0.324788	0.209197	0.053598	1.000000	
	0.0000	0.0000	0.0000	———	
FDV	0.389533	0.819096	−0.242740	0.043480	1.000000
	0.0000	0.0000	0.0000	0.0007	———

Source: Authors computation

Table 4
CIPS panel unit-root tests.

Variable	At Levels		First Difference	
	Constant	Constant & trend	Constant	Constant & trend
GHG	−2.455	2.526	−4.198***	−4.403***
GDP	−2.150	−2.397	−2.710***	−2.740***
RENE	−2.279	−2.477	−3.995***	−4.120***
DMCC	−1.531	−1.750	−4.592***	−4.483***
FDV	−1.698	−2.631*	−4.280***	−4.452***

Note: *** and * indicate rejection of the null hypotheses at the 1% and 10% level of significance respectively.

Table 5
PVAR(2) stability test.

Eigenvalue	Modulus
0.6236768	0.6237815
0.6236768	0.6237815
0.5335252	0.5759581
0.5335252	0.5759581
0.4960279	0.4960279
0.3621971	0.3622369
0.3621971	0.3622369
0.3510237	0.3510237
0.3259552	0.3408959
0.3259552	0.3408959

Note: At least one eigenvalue lies outside the unit circle. PVAR does not satisfy stability conditions.

production activities will in turn increase demand for fossil fuels and other non-renewable energy sources, thereby increasing the greenhouse gas emissions in terms of carbon dioxide emissions. Put differently, a decrease in greenhouse gas emissions would increase economic growth and financial development in an economy where non-renewable energy sources have been replaced with adequate renewable energy sources, as displayed in Fig. 1. This finding is consistent with [22,24] who posited that an increase in environmental degradation is traceable to financial development. However, this finding is not supported by Ref. [23] who found an inverse relationship between environmental degradation and financial development. Conversely, renewable energy consumption reacts negatively to shocks in greenhouse gas emissions. If sound and effective economic and environmental policy were in place, an increase in greenhouse gas emissions would not hurt financial development and economic growth respectively. This finding corroborates with [11,15,16,19]; Akadiri et al. (2019, 2020) [34,35]; [4,12,36]. In addition, our result shows that domestic material consumption reacts negatively to shocks in greenhouse gas emissions before 4 months, and then reacts positively afterward. This is an indication that domestic material consumption does not contribute positively to greenhouse gas emissions until after 4 months, while greenhouse gas emissions react positively to its own shocks. This finding agrees with [4] who found DMCC to have reduced greenhouse gas emissions in some countries in the short run. However, our finding is not consistent with [3] who revealed that DMCC exerts upward pressure on environmental degradation.

Fig. 2 reveals the reactions of greenhouse gas emissions, renewable energy consumption, financial development, and domestic material consumption to shocks in economic growth. The IRF results as reported in Fig. 2 shows that a shock to economic growth leads to an increase in renewable energy consumption, domestic material consumption, and financial development. This result resonates a number of existing studies on the relationship between renewable energy consumption and economic growth [11,15,16]; Akadiri et al., 2019, 2020; [4,12,36,37]. The result echoes the relationship between domestic material consumption and economic growth [3,4,9] and further shows the relationship between economic growth and financial development [22]; 2018; [23,35]. Developed countries with a high rate of economic activities and financial development have adequate and sufficient capital to acquire and put in place renewable energy sources and energy-saving technologies in place of non-renewable energy sources for consumption and production activities. While the level of economic growth on the other hand, also determine availability and the level at which domestic material is consumed. In addition, the result shows that greenhouse gas emissions react negatively to shocks in economic growth. This is an indication that the region has sound energy and environmental policy responses in place to combat environmental degradation of the region as economic activities that have been reported to stimulate environmental pollution increase in the region. This outcome is

Table 6
GMM Estimates of PVAR (2) model.

Variables	Equations				
	GHG_t	GDP_t	$RENE_t$	$DMCC_t$	FDV_t
GHG_{t-1}	1.3408*** (0.0468)	0.0546** (0.0211)	−0.03419 (0.0385)	−0.0214 (0.0159)	0.0226 (0.0150)
GHG_{t-2}	−0.2948*** (0.0434)	0.0007 (0.0170)	0.0083 (0.0246)	−0.0087 (0.0096)	0.0084 (0.0122)
GDP_{t-1}	0.0930 (0.0663)	1.1594*** (0.0501)	−0.3246*** (0.0745)	−0.0155 (0.0225)	−0.0962*** (0.0304)
GDP_{t-2}	−0.0352 (0.0551)	−0.2291*** (0.0449)	0.12147** (0.0630)	−0.0054 (0.0181)	0.0689** (0.0274)
$RENE_{t-1}$	−0.0071 (0.0194)	−0.0146 (0.0130)	1.3310*** (0.0426)	0.0015 (0.0112)	0.0012 (0.0058)
$RENE_{t-2}$	0.0130 (0.0193)	0.0186 (0.0129)	−0.3132*** (0.0435)	0.0015 (0.0113)	0.0025 (0.0058)
$DMCC_{t-1}$	0.1230** (0.0544)	0.0308 (0.0309)	0.0137 (0.0616)	1.3585*** (0.0342)	0.0349 (0.0218)
$DMCC_{t-2}$	−0.0726 (0.0481)	−0.0432 (0.0283)	0.0145 (0.0571)	−0.3382*** (0.0329)	−0.0299 (0.0195)
FDV_{t-1}	−0.2585** (0.0943)	0.1677** (0.0633)	0.3857*** (0.0885)	0.0196 (0.0308)	1.3892*** (0.0492)
FDV_{t-2}	0.0974 (0.0697)	−0.0429 (0.0574)	−0.1198* (0.0675)	−0.0083 (0.0229)	−0.3551*** (0.0473)

Note: ***, **, and * denote significance levels at 1%, 5% and 10% while standard errors are presented in parentheses. All the variables are in their growth rates.

Table 7
PVAR (2) Granger causality test.

Dependent Variable	GHG_t	GDP_t	$RENE_t$	$DMCC_t$	FDV_t	$_{ALL}\chi^2$-stat [prob.]
GHG_t	...	7.862** [0.020]	4.307 [0.116]	7.545*** [0.023]	17.305*** [0.000]	45.027*** [0.000]
GDP_t	18.223*** [0.000]	...	7.916** [0.019]	4.347 [0.114]	27.918*** [0.000]	64.864*** [0.000]
$RENE_t$	2.474 [0.290]	64.553*** [0.000]	...	0.068 [0.967]	43.909*** [0.000]	69.918*** [0.000]
$DMCC_t$	6.637** [0.036]	7.177** [0.028]	5.586* [0.061]	...	0.616 [0.735]	20.736** [0.008]
FDV_t	11.233*** [0.004]	13.185*** [0.001]	17.823*** [0.000]	2.554 [0.279]	...	44.058*** [0.000]

Note: ***, **, and * denote significance levels at 1%, 5% and 10% while p-values are presented in parentheses. All the variables are in their growth rates.

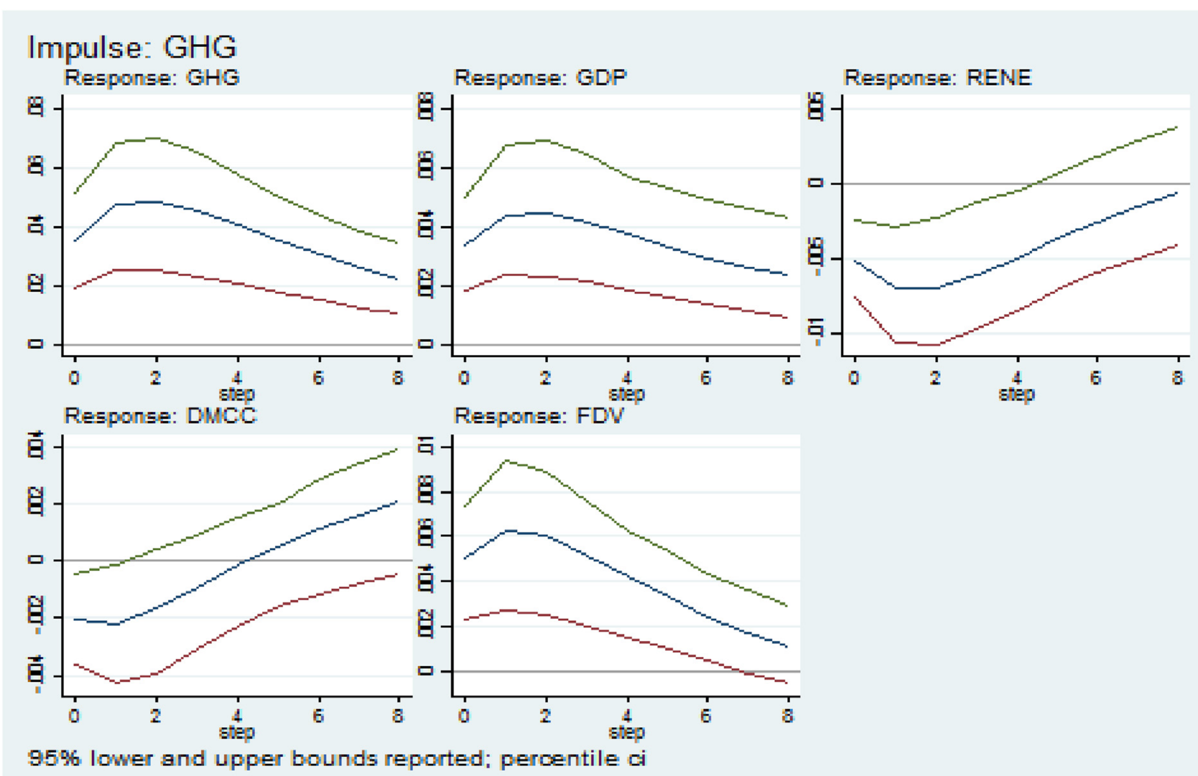


Fig. 2. Shocks to greenhouse gas emissions.

in line with the study of [38–41]; Akadiri et al. (2019, 2020) and [4] who reported an inverse relationship between economic growth and environmental degradation.

Furthermore, Fig. 3 reveals the reactions of financial development; domestic material consumption, economic growth, and greenhouse gas emissions to shocks in renewable energy consumption. Results as reported in Fig. 3 show that a rise in renewable energy consumption leads to an increase in economic growth and domestic material consumption. This result resonates a number of existing studies on the interrelationship between renewable energy consumption and economic growth (see Refs. [17,19]; Akadiri et al., 2019, 2020 [14,42]; Musa et al., 2021) and between renewable energy and domestic material consumption [4] respectively. Also, the result shows that greenhouse gas emissions and financial development react negatively to shocks in renewable energy consumption. This indicates that, as renewable energy increases, greenhouse gas emissions decrease, and vice versa. Implementation of renewable energy sources would lead to energy-saving technologies; hence a decrease in the non-renewable energy source. In addition, in the short run, implementation of renewable energy might be costly, thus leading to a decrease in financial development. This outcome is in line with the study of [11,16]; Akadiri et al. (2019, 2020) who reported an inverse relationship between renewable energy consumption and environmental degradation. However, we found financial development to react inversely to shocks in renewable energy. This result is inconsistent with the outcomes of Akadiri et al. (2019, 2020).

Fig. 4 shows the reactions of renewable energy consumption, financial development, economic growth, and greenhouse gas emissions to shocks in domestic material consumption. Fig. 4 shows that a rise in domestic material consumption leads to an increase in economic growth and greenhouse gas emissions. That is, an increase in the level of domestic material consumption increases economic activities and thus greenhouse gas emissions. This result resonates with a number of existing studies on the relationship between renewable energy consumption and domestic material consumption (see Refs. [3,4] and between economic growth and domestic material consumption [3,43] respectively. Also, the result shows that renewable energy consumption reacts negatively to shocks in domestic material consumption. This resonates with our earlier claim that an increase in renewable energy necessitates a decrease in the use of domestic material consumption that generates environmental pollution. This result is consistent with the study of [4] who reported an inverse relationship between renewable energy consumption and domestic material consumption. However, we found that financial development reacts negatively (after 3 months) and positively (after 4 months) to shock in domestic material consumption. This result is inconsistent with the outcomes of [4,9].

Lastly, Fig. 5 shows the reactions of renewable energy consumption; domestic material consumption, economic growth, greenhouse gas emissions to shocks in financial development. Results as reported in Fig. 5 show that an increase in financial development stimulates an increase in economic growth and domestic material consumption. This indicates that financial development stimulates economic growth and hence increases the level of domestic material consumption, and vice versa. This result echoes a number of existing studies on the relationship between domestic material consumption and economic growth (see Akadiri et al., 2019 [9,44,45]; lucak, Koçak, Erdoğan, and Kassouri, 2020; and [46]. In addition, the result shows that shocks to financial development positively affect renewable energy. That is, a positive shock to financial development increases renewable energy respectively (see Ref. [4]. This result is consistent with the outcomes of [47,48]. Also, the result shows that greenhouse gas emissions react negatively to shocks in financial development. This indicates that positive shocks to financial development decrease environmental pollution. This finding is in line with the study of Shahbaz et al., 2018; Akadiri et al. (2019, 2020) who reported an inverse relationship between financial development and environmental degradation (see Fig. 6).

Table 7 reports the causal nexus among greenhouse gas emissions, gross domestic product, renewable energy consumption, domestic material consumption, and financial development

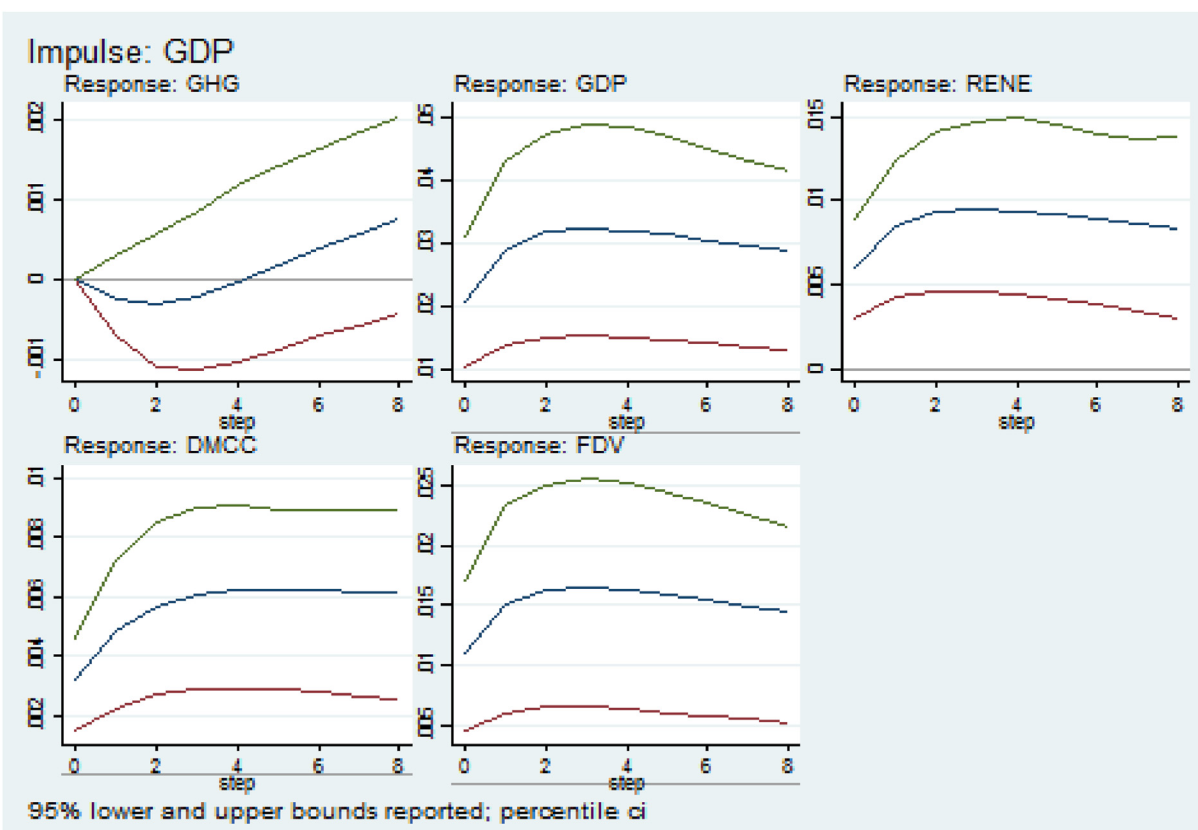


Fig. 3. Shocks to economic growth.

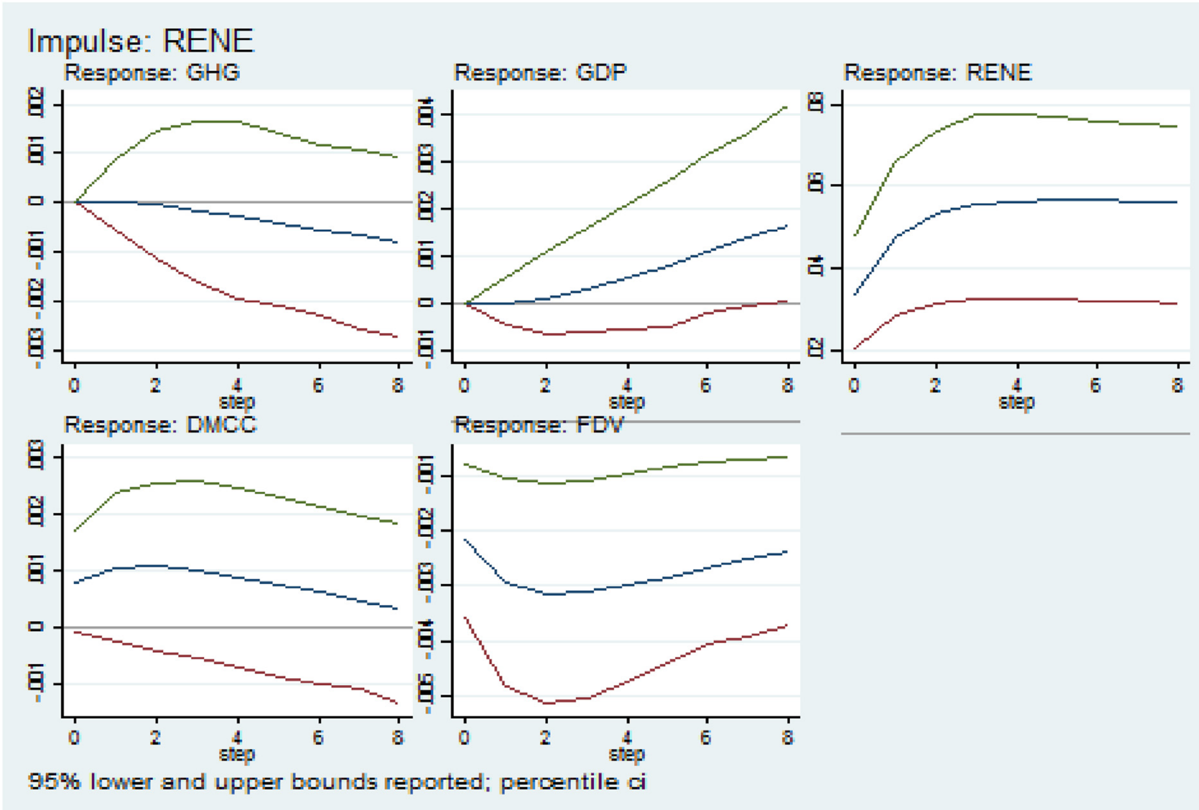


Fig. 4. Shocks to renewable energy consumption.

respectively. The PVAR (2) Granger causality result reveals that a change to greenhouse gas emissions can be used to predict changes in gross domestic product, domestic material consumption, and financial development respectively. Therefore, the causal impact of greenhouse gas emissions on the gross domestic product, domestic material consumption, and financial development emphasizes that increases in greenhouse gas emissions dampen the environment, as economic activities, domestic material consumption, and financial services increases. This result is consistent with the findings of [4,9] respectively. However, the result shows that greenhouse gas emission does not cause renewable energy consumption. This implies that a rise in environmental degradation does not necessarily increase demand for renewable energy sources; this result does not resonate with the findings of [4,35,36].

Furthermore, the gross domestic product causes greenhouse gas emissions, renewable energy consumption, domestic material consumption, and financial development respectively. This indicates not only a bi-directional causality between greenhouse gas emissions and economic growth but also that a change in renewable energy consumption and financial development will cause economic growth to change respectively. The effect of economic growth on environmental degradation, renewable energy consumption, and financial development reveals the potential impact of a change in economic activities on the environment, which also necessitates a switch to more efficient and energy-saving technologies for production amidst a change in financial services, hence financial development. These empirical results resonate with the findings of Akadiri et al. (2019, 2020) and [4,36] who concluded that economic growth causes environmental degradation, renewable energy consumption, and financial development. Also, economic growth causes domestic material consumption. This empirical result could be due to fossil fuel energy consumption associated with materials required for stimulating economic growth in the EU-28 member countries.

The empirical result also shows that renewable energy consumption causes economic growth, financial development, and domestic material consumption but the causal relationship between renewable energy consumption and greenhouse gas emission is insignificant. This result suggests that a change in renewable energy consumption can predict a change in economic growth, domestic material consumption, and financial development. These findings confirm existing studies that have reported that an increase in renewable energy consumption has the potential power to increase economic growth (see Akadiri et al., 2019, 2020; [13,35]. This result also resonates with the findings of Akadiri et al. (2019) [4,36], and [21] where it was concluded that a switch from the non-renewable energy source to renewable energy source would lead to a sound and clean environment for both the immediate and future generation, thus, an improvement in economic growth and performances. Also, renewable energy consumption does not cause greenhouse gas emissions. This empirical result complements the efforts of the EU-28 member countries in putting in place sound economic and environmental policies that curtail environmental degradation in the region. This is achieved by replacing industrial production activities with renewable energy sources, and fossil fuel automobiles with electric cars that generate little or no emissions among other green energy policies/energy saving-technologies to reduce to the barest minimum environmental pollution in the region.

In addition, we found that domestic material consumption causes greenhouse gas emissions only. The causal relationship between domestic material consumption and other variables such as

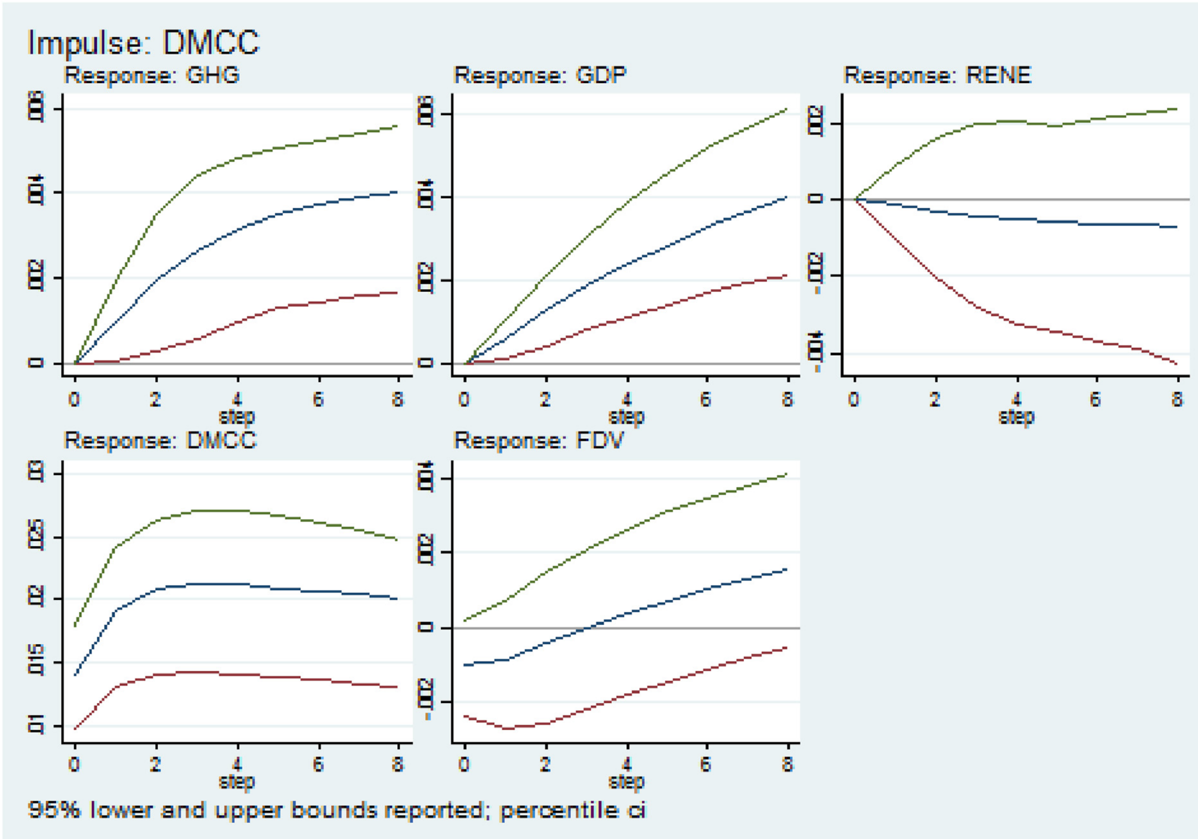


Fig. 5. Shocks to domestic material consumption.

economic growth, renewable energy consumption, and financial development is although insignificant. This result indicates that a change in domestic material consumption can only predict greenhouse gas emissions but not economic growth, renewable energy consumption, and financial development. Both the government and policymakers intervention is required in the EU-28 countries if any meaningful environmental pressure caused by human and economic activities would be controlled and curtailed as shown by our results. Although [49,50], Heil and Seldon and [51] in their empirical analysis, found an inverted-U shaped and enormous turning points between CO_2 emissions and economic growth, our results lend support from the study [4] that increases in domestic material consumption increases greenhouse gas emissions, and confirmed Mazzanti and Musolesi (2013) findings that, there is a direct relationship between CO2 emissions and growth in most of the developed countries.

Lastly, on the causal relationship among the variables under investigation, the result shows that financial development causes environmental degradation, economic growth, and renewable energy consumption. This result suggests that a shock to financial development causes a shock to environmental degradation, economic growth, and renewable energy consumption. This result emphasizes that a change in financial development tends to cause a change in economic activities via industrial activities, the use of automobiles that depends on non-renewable energy sources (if the certain policy to cushion the use of such automobile engines is not in place) among others. This dampens the environment and economic growth – although increasing demand for renewable energy sources could face the situation. Therefore, our result is consistent with the findings of Saint Akadiri et al. (2019), Akadiri and Akadiri (2020) and [4,44,45], Ulucak, Koçak, Erdoğan, and Kassouri, (2020) and Wang, Wang, Fan, [46]. However, the result shows that financial development does not cause domestic material consumption. This implies that a change in financial development does not necessarily impact the amount of domestic material consumed.

5. Conclusion

This paper seeks to determine the cross-country effects from the causal relationship between greenhouse gas emissions, economic growth, renewable energy consumption, domestic material consumption, and financial development in order to offer environmental sustainability inference targets for the European Union (EU-28) member countries. In doing this, we applied the panel VAR estimation procedure over the period 2000:Q1–2017:Q4. The empirical results found that the shocks to economic growth, renewable energy, domestic material consumption, financial development, and greenhouse gases affect the sustainable environment in the EU-28. Specifically, the shocks to renewable energy and financial development dampen or reduce environmental degradation, but the shocks to domestic material consumption and greenhouse gas emission deteriorate the quality of the environment. Additionally, the shock to economic growth reduces environmental degradation up to the 4th horizon after which economic expansion begins to deteriorate the environment.

Indicatively, the panel causality results indicate that a shock to greenhouse gas emissions Granger-cause economic growth, domestic material consumption, and financial development. The result also found that changes in economic growth could predict greenhouse gas emission, renewable energy consumption,

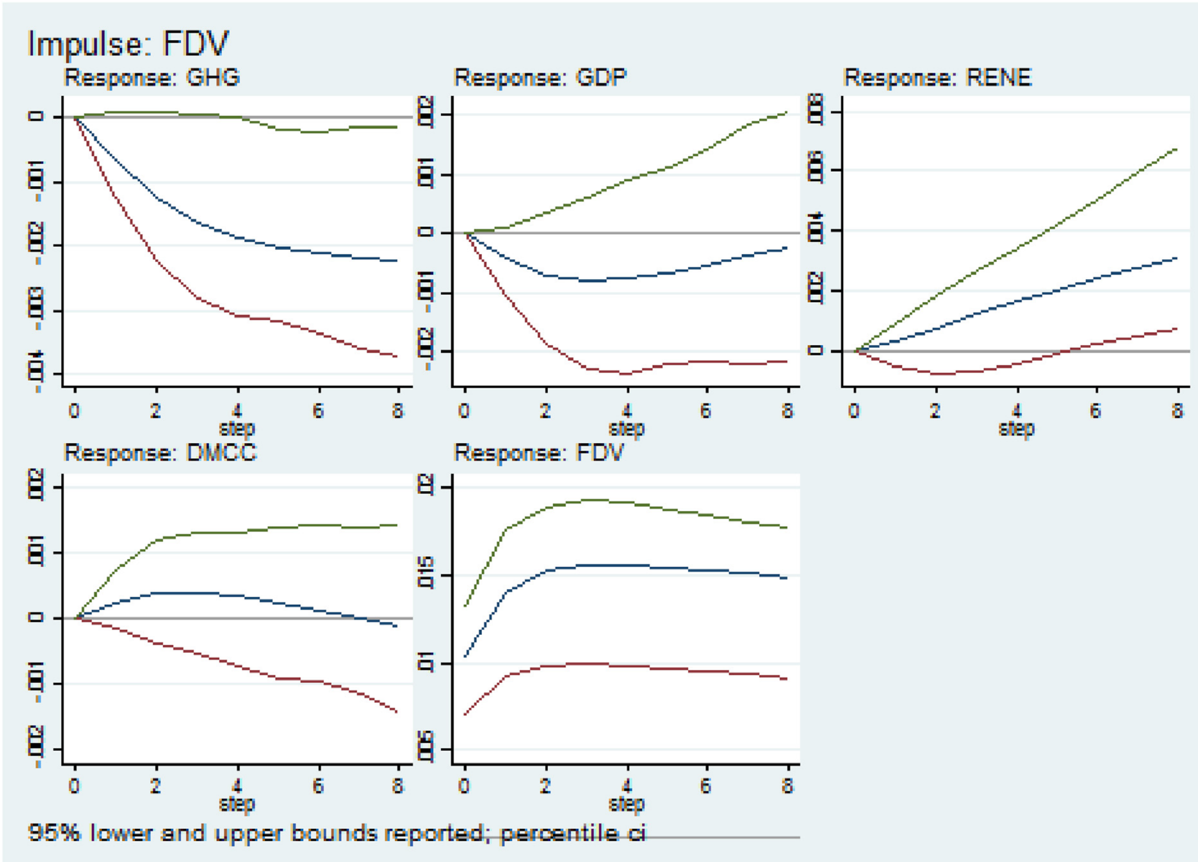


Fig. 6. Shocks to financial development.

domestic material consumption, and financial development. The results further revealed that changes in renewable energy Granger-cause economic growth, domestic material consumption, and financial development while domestic material consumption only predicts greenhouse gas emissions. The causality between financial development and the rest of the variables showed that financial development shocks predict greenhouse gas emissions, economic growth, and renewable energy consumption. These results imply that a bidirectional causality exists between greenhouse gas emissions and the rest of the variables in this study except renewable energy where the causality is unidirectional (one-way). Similarly, a bidirectional causality is implied between economic growth and renewable energy, economic growth, and financial development, and again financial development and renewable energy while a unidirectional (one-way) causal nexus flows from economic growth to domestic material consumption.

5.1. Policy insights

For policy relevance, the European Union member countries need to further push for the bloc's drive toward achieving sustainable consumption and production agenda as outlined in Sustainable Development Goal (SDG 12) of the United Nations Development Programme. Although the EU has achieved great success in this perspective, the results in this study positioned that the role of the individual states, especially the low-income members of the union should measure up to the large economies in the EU. In the aspects of renewables, financial development, and low level of greenhouse gas emissions, as much as many EU member states are attaining the EU member states' targets, more incentives such as energy credit and financing should further be made available to other member states that are struggling in meeting these targets.

CRediT authorship contribution statement

Ojonugwa Usman: Writing – review & editing, Formal analysis, Investigation, Methodology, Visualization, Validation, Supervision. **Andrew Adewale Alola:** Data curation, Writing – review & editing, Supervision, Corresponding. **Seyi Saint Akadiri:** Writing – review & editing, Supervision.

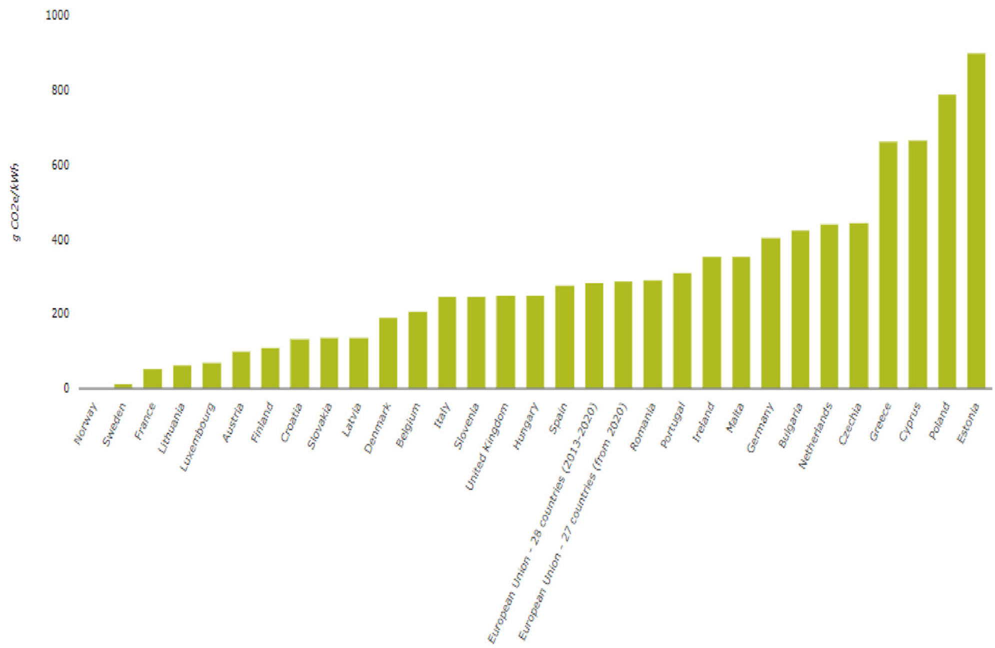
Declaration of competing interest

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.

APPENDIX

Appendices

Appendix A. The EU countries' greenhouse gas emission intensity of electricity generation, adopted from the European Environment Agency (EEA) database



Appendix B. Highlight of material consumption-related literature for European Union

Author	Method/Country	Period	Study objective
[53]	Statistical and time series analysis- EU-15	1970–2001	Compare the level and composition of domestic material consumption (DMC) in the EU-15 member states and identify determinants of the observed differences
Schoer et al. (2006)	Hybrid input-output life cycle assessment method/EU		Method of calculation of the “Raw Material Consumption” (RMC)
[54]	Exergoecology method	1995–2012	To examine the material flow analysis
[55]	Log-Mean Divisia Index Method (LMDI)/EU	2002–2014	Decomposition of the data on the Domestic Material Consumption (DMC)
[56]	Two-stage least square (2SLS)	2000–2014	The causal impact of material productivity on six macroeconomic indicators
[57]	Factorial and regression analysis)/EU-28	2001–2018	Circular economy, sustainable consumption patterns, and sustainable production patterns as determinant of resource productivity.
[58]	Panel cointegration and panel vector error correction models)/EU-28		GDP, Energy Consumption, and Material Consumption as determinants of waste generation
[59]	A spatial panel data analysis/Selected European countries.	2000–2016	Examining GDP per capita, final energy consumption per capita and the share of the construction sector in GDP as drivers of material consumption.
[1]	Cointegration//EU-28	2000–2017	Determinants of greenhouse gas
[60]	Data envelopment analysis (DEA)/EU-28	2000–2018	The effect of fossil fuel energy consumption, renewable energy consumption, CO2 emissions, domestic material consumption and recycled municipal waste) on total factor productivity change (TFPCH)

References

[1] A.A. Alola, I. Ozturk, Mirroring risk to investment within the EKC hypothesis in the United States, J. Environ. Manag. 293 (2021) 112890.
[2] E.N. Udemba, H. Güngör, F.V. Bekun, D. Kirikkaleli, Economic performance of India amidst high CO2 emissions, Sustainable Production and Consumption 27 (2021) 52–60.
[3] M. Ahmad, S.I. Khattak, Is aggregate domestic consumption spending (ADCS) per capita determining CO2 emissions in South Africa? A New Perspective, Environ. Resour. Econ. 75 (3) (2020) 529–552.
[4] A.A. Alola, S.S. Akadiri, O. Usman, Domestic material consumption and greenhouse gas emissions in the EU-28 countries: implications for environmental sustainability targets, Sustain. Dev. (2020), https://doi.org/10.1002/sd.2154.
[5] European Commission, Sustainable development. https://ec.europa.eu/environment/eussd/escp_en.htm#: :text=The%20Sustainable%20Consumption%20and%20Production,SCP%2FSIP)%20Action%20Plan.&text=It%20also%20seeks%20to%20encourage,advantage%20of%20opportunities%20to%20innovate, 2020. (Accessed 18 December 2020).
[6] European Commission, Sustainable product policy. https://ec.europa.eu/jrc/en/research-topic/sustainable-product-policy, 2018. (Accessed 18 December 2020).
[7] European Economic Area, Primary and final energy consumption in Europe. https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-11/assessment, 2020b. (Accessed 18 December 2020).
[8] United States Energy Information Administration, Energy and the environment explained, Greenhouse gases (2021). https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases.php. (Accessed 20 July 2021).
[9] S.A. Sarkodie, Causal effect of environmental factors, economic indicators and

domestic material consumption using frequency domain causality test, Sci. Total Environ. (2020) 139602.
[10] S. Saint Akadiri, A.C. Akadiri, Interaction between CO 2 emissions, energy consumption and economic growth in the Middle East: panel causality evidence, Int. J. Energy Technol. Pol. 16 (2) (2020) 105–118.
[11] E. Dogan, I. Ozturk, The influence of renewable and non-renewable energy consumption and real income on CO 2 emissions in the USA: evidence from structural break tests, Environ. Sci. Pollut. Control Ser. 24 (11) (2017) 10846–10854.
[12] M.A. Destek, A. Aslan, Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries, Renew. Energy 151 (2020) 1298–1306.
[13] G.N. Ike, O. Usman, A.A. Alola, S.A. Sarkodie, Environmental quality effects of income, energy prices and trade: the role of renewable energy consumption in G-7 countries, Sci. Total Environ. (2020a) 137813.
[14] P.T. Iorember, G. Jelilov, O. Usman, A. Işık, B. Celik, The influence of renewable energy use, human capital, and trade on environmental quality in South Africa: multiple structural breaks cointegration approach, Environ. Sci. Pollut. Control Ser. 28 (2021) 13162–13174.
[15] A. Alvarez-Herranz, D. Balsalobre-Lorente, M. Shahbaz, J.M. Cantos, Energy innovation and renewable energy consumption in the correction of air pollution levels, Energy Pol. 105 (2017) 386–397.
[16] N. Apergis, M.B. Jebli, S.B. Youssef, Do renewable energy consumption and health expenditures decrease carbon dioxide emissions? Evidence for sub-Saharan Africa countries, Renew. Energy 127 (2018) 1011–1016.
[17] S.P. Nathaniel, C.O. Iheonu, Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption, Sci. Total Environ. 679 (2019) 337–345.
[18] U. Al-Mulali, I. Ozturk, S.A. Solarin, Investigating the environmental Kuznets curve hypothesis in seven regions: the role of renewable energy, Ecol. Indicat. 67 (2016) 267–282.
[19] E. Dogan, F. Seker, Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy, R*enew. Energy* 94 (2016) 429–439.
[20] F.V. Bekun, A.A. Alola, S.A. Sarkodie, Toward a sustainable environment: nexus between CO2 emissions, resource rent, renewable and non-renewable energy in 16-EU countries, Sci. Total Environ. 657 (2019) 1023–1029.
[21] A. Usman, S. Ullah, I. Ozturk, M.Z. Chishti, S.M. Zafar, Analysis of asymmetries in the nexus among clean energy and environmental quality in Pakistan, Environ. Sci. Pollut. Control Ser. (2020a) 1–12.
[22] M. Shahbaz, S.J.H. Shahzad, N. Ahmad, S. Alam, Financial development and environmental quality: the way forward, Energy Pol. 98 (2016) 353–364.
[23] S. Adams, E.K.M. Klobodu, Financial development and environmental degradation: does political regime matter? J. Clean. Prod. 197 (2018) 1472–1479.
[24] L. Charfeddine, K.B. Khediri, Financial development and environmental quality in UAE: cointegration with structural breaks, R*enew. Sustain. Energy Rev.* 55 (2016) 1322–1335.
[25] M.A. Baloch, I. Ozturk, F.V. Bekun, D. Khan, Modeling the dynamic linkage between financial development, energy innovation, and environmental quality: does globalization matter? Bus. Strat. Environ. (2020).
[26] C. Yuan, R. Chen, Policy transmissions, external imbalances, and their impacts: cross-country evidence from BRICS, China Econ. Rev. 33 (2015) 1–24.
[27] C.A. Sims, Macroeconomics and reality, Econometrica 48 (1980) 1–48.
[28] M. Balcilar, D. Roubaud, O. Usman, M. Wohar, Testing the asymmetric effects of exchange rate pass-through in BRICS countries: does the state of the economy matter? World Econ. (2020) https://doi.org/10.1111/twec.12990.
[29] J.F. Kiviet, On bias, inconsistency and efficiency of various estimators in dynamic panel data models, J. Econom. 68 (1995) 53–78.
[30] M.J.G. Bun, M.A.(Carree, Bias-corrected estimation in dynamic panel data models, J. Bus. Econ. Stat. 23 (2005) 200–210.
[31] M. Arellano, O. Bover, Another look at the instrumental variable estimation of errorcomponents models, J. Econom. 68 (1995) 29–51.
[32] K. Hayakawa, Improved GMM estimation of panel VAR models, Comput. Stat. Data Anal. 100 (2016) 240–264.
[33] J. Hartwig, Is health capital formation good for long-term economic growth? -Panel Granger-causality evidence for OECD countries, J. Macroecon. 32 (2010) 314–325.
[34] O. Usman, P.T. Iorember, I.O. Olanipekun, Revisiting the environmental Kuznets curve (EKC) hypothesis in India: the effects of energy consumption and democracy, Environ. Sci. Pollut. Control Ser. 26 (13) (2019) 13390–13400.
[35] O. Usman, S.S. Akadiri, I. Adeshola, Role of renewable energy and globalization on ecological footprint in the USA: implications for environmental sustainability, Environ. Sci. Pollut. Control Ser. (2020b) 1–13.
[36] A.A. Alola, U.V. Alola, S. Saint Akadiri, Renewable energy consumption in Coastline Mediterranean Countries: impact of environmental degradation and housing policy, Environ. Sci. Pollut. Control Ser. 26 (25) (2019) 25789–25801.
[37] O. Usman, A.A. Alola, S.A. Sarkodie, Assessment of the role of renewable energy consumption and trade policy on environmental degradation using innovation accounting: evidence from the US, Renew. Energy 150 (2020c) 266–277.
[38] U. Soytas, R. Sari, Energy consumption and income in G-7 countries, J. Pol. Model. 28 (2006) 739–750.
[39] N. Apergis, J. Payne, CO2 emissions, energy usage and output in Central America, Energy Pol. 37 (2009) 3282–3286.
[40] N. Apergis, Environmental Kuznets curves: new evidence on both panel and country-level CO2 emissions, Energy Econ. 54 (2016) 263–271.
[41] N. Apergis, C. Christou, R. Gupta, Are there environmental Kuznets curves for US state-level CO2 emissions? Renew. Sustain. Energy Rev. 69 (2017) 551–558.
[42] G.N. Ike, O. Usman, S.A. Sarkodie, Fiscal policy and CO2 emissions from heterogeneous fuel sources in Thailand: evidence from multiple structural breaks cointegration test, Sci. Total Environ. 702 (2020b) 134711.
[43] W. Brock, S. Taylor, The green Solow model, J. Econ. Growth 15 (2010) 127–153.
[44] G.H. Popescu, J.V. Andrei, E. Nica, M. Mieilă, M. Panait, Analysis on the impact of investments, energy use and domestic material consumption in changing the Romanian economic paradigm, Technol. Econ. Dev. Econ. 25 (1) (2019) 59–81.
[45] P. Agnolucci, F. Flachenecker, M. Söderberg, The causal impact of economic growth on material use in Europe, Journal of Environmental Economics and Policy 6 (4) (2017) 415–432.
[46] H. Wang, Y. Wang, C. Fan, X. Wang, Y. Wei, Z. Zhang, et al., Material Consumption and Carbon Emissions Associated with the Infrastructure Construction of 34 Cities in Northeast China, Complexity, 2020.
[47] J. Kim, K. Park, Financial development and deployment of renewable energy technologies, Energy Econ. 59 (2016) 238–250.
[48] Q. Ji, D. Zhang, How much does financial development contribute to renewable energy growth and upgrading of energy structure in China? Energy Pol. 128 (2019) 114–124.
[49] M. Galeotti, A. Lanza, F. Pauli, Reassessing the environmental Kuznets curve for CO2 emissions: a robustness exercise, Ecol. Econ. 57 (1) (2006) 152–163.
[50] M.A. Cole, US environmental load displacement: examining consumption, regulations and the role of NAFTA, Ecol. Econ. 48 (4) (2004) 439–450.
[51] M. Galeotti, A. Lanza, Richer and cleaner? A study on carbon dioxide emissions in developing countries, Energy Pol. 27 (10) (1999) 565–573.
[53] H. Weisz, F. Krausmann, C. Amann, N. Eisenmenger, K.H. Erb, K. Hubacek, M. Fischer-Kowalski, The physical economy of the European Union: cross-country comparison and determinants of material consumption, Ecol. Econ. 58 (4) (2006) 676–698.
[54] G. Calvo, A. Valero, A. Valero, Material flow analysis for Europe: an exergoecological approach, Ecol. Indicat. 60 (2016) 603–610.
[55] M. Drastichová, Decomposition analysis of the material consumption in the European Union, Ekonomický časopis 64 (7) (2016) 646–665.
[56] F. Flachenecker, The causal impact of material productivity on macroeconomic competitiveness in the European Union, Environ. Econ. Pol. Stud. 20 (1) (2018) 17–46.
[57] G. Pineiro-Villaverde, M.T. García-Álvarez, Sustainable consumption and production: exploring the links with resources productivity in the EU-28, Sustainability 12 (21) (2020) 8760.
[58] R. Gardiner, P. Hajek, Effect of GDP, energy consumption, and material consumption on waste generation: the case of EU-28 countries, in: Eurasian Economic Perspectives, Springer, Cham, 2020, pp. 73–85.
[59] I. Telega, A. Telega, Driving factors of material consumption in European countries–spatial panel data analysis, Journal of Environmental Economics and Policy 9 (3) (2020) 269–280.
[60] C. Bampatsou, G. Halkos, C. Beneki, Energy and material flow management to improve EU productivity, Econ. Anal. Pol. 70 (2021) 83–93.
[61] R.F. Engle, Autoregressive conditional heteroskedasticity with estimates of the variance of U.K. Inflation, Econometrica 50 (1982) 987–1008.
[62] J.M. Wooldridge, in: Introductory Econometrics, fourth ed., South-Western, Cengage Learning, 2009.
[63] M. Balcilar, O. Usman, Exchange rate and oil price pass-through to inflation in BRICS countries: evidence from the spillover index and rolling-sample analysis, Energy 229 (2021) 120666.
[64] M. Balcilar, D. Roubaud, O. Usman, M.E. Wohar, Moving out of the linear rut: a period-specific and regime-dependent exchange rate and oil price pass-through in BRICS countries, Energy Econ. 98 (2) (2021) 105249.
[65] L. Bonga-Bonga, Fiscal policy, monetary policy and external imbalances: cross-country evidence from Africa's three largest economies, J. Int. Trade Econ. Dev 28 (2) (2019) 123–136.