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Domestic material consumption and greenhouse gas emissions in the EU-28 countries: Implications for environmental sustainability targets

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Abstract

In spite of the achievements of the European Union (EU) member countries with respect to the sustainable development goals (SDGs) 2030 targets, the member countries have reportedly under-performed in a specific drive towards the SDG 12 (Sustainable Consumption and Production [SCP]). In advancing evidence to this insight, the current study examines the role of domestic material consumption, income and renewable energy utilisation in the panel of the EU-28 environmental sustainability targets. In specific, we find that domestic material consumption worsens the bloc's environmental quality in both the immediate and long term. Although an increase in per capita income level aids environmental sustainability in the long term, the short-run effect shows that per capita income growth triggers greenhouse gas emissions. The study further reveals that while cleaner energy development (renewables) improves the countries' environmental sustainability in both the short and long run, the level of real income is yet detrimental to environmental quality. Moreover, consumption of domestic materials, the share of renewable energy utilisation and real income contribute to greenhouse gas emissions in countries like Czech Republic, Lithuania and Malta. Thus, this study suggests country-specific policies that primarily target domestic consumption and cleaner energy development to achieve environmental sustainability targets among the EU member states.

KEYWORDS

cleaner energy, environmental sustainability, EU member states, real income, sustainable consumption and production

1 | INTRODUCTION

In recent years, there have been growing concerns and awareness on the grievous impacts of greenhouse gas emissions, precisely global warming on human and the environment at large by individuals, firms and government, as well as policymakers. These impacts, particularly on the environment, have been of concern to the advanced nations of the world who are primarily industrialized nations. Until recently,[1] some of these nations depend heavily on non-renewable energy sources for production activities either for domestic consumption or to promote trade among their partner-countries and as a medium of transferring technological expertise to the developing, emerging and underdeveloped nations. It is paramount to point out here that, these developing, emerging and underdeveloped nations are equally not left out of these environmental menaces. They are not immune to the environmental turmoil as long as they engage in international trade, via importation of non-renewable energy, technological transfers and its attendant products, which in one way or the other increase real income. This has been documented in the energy literature as one of the major determinants of carbon dioxide (CO_2) emissions (Acaravci &

Ozturk, 2010; Akadiri, Bekun, Taheri, & Akadiri, 2019; Ozturk & Acaravci, 2010; Saint Akadiri, Alkawfi, Uğural, & Akadiri, 2019; Saint Akadiri, Alola, & Akadiri, 2019; Saint Akadiri, Alola, Akadiri, & Alola, 2019). Thus, human – in terms of their social interactions – firms, and governments – in terms of their economic and environmental dealings – either via production or consumption activities have contributed to the environmental hiccups the world economies are facing today.

Climate change is a menace to the world economies as well as to the sustainable development targets. The Intergovernmental Panel on Climate Change (2014; *IPCC*) argued that man-made GHG emissions are the major contributor to the increase in the world average temperature over the past 25 decades ago. Man-made GHG emissions are the aftermath of flaring fossil fuels by households and industries in terms of house appliances, automobiles and power plants. In addition, waste and farming decaying in landfills are other sources of GHG emissions that have yielded a slight increase in recent time. Meanwhile, in 2017 and 2018, there was a decline in GHG emissions by 19 and 21% compared with the estimate in1990. Thus, this indicates an outright decline of about 935 million tonnes and 1,018 million tonnes of carbon dioxide equivalents (CO_2e), thereby placing the EU countries on the pathway to achieving its 2020 target (the goal of reducing GHG emissions by 20 and 40% by 2030 compared to 1990). Going by sectors, compared with 1990, the share of most sectors to GHG emissions has decreased. In 2017, the transportation sector recorded about 23.8%, 25.5% shared by users of fuel combustion and 29.0% share by the energy producing industries of the total GHG emissions reported (see https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4a.html).

Going by the graphical representation in Figure 1, it appears that the EU-28 countries have experienced a decline pattern in GHG emissions trend between periods 1990 and 1999, except for 1996 where the region had a relative boom. This is due to tough weather conditions (cold winter) that led to increase heating temperature requirements, while the region had relatively stable progression of GHG emission between 1999 and 2008. Consequent upon the global economic/financial downturn and decline in industrial activities, the region recorded a drastic decline in GHG emissions in 2009. Furthermore, we observed that the GHG emissions fluctuated between 2010 and 2018. The GHG emissions increased in 2010, decreased between 2011 and 2014 and picked up again between 2015 and 2017. A 2.1% increase in GHG emissions was recorded in 2018, which amounted to about 83.6 million tonnes of CO_2e, compared to the statistics reported for 2017. (see https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4a.html).

Going by the share of some of the EU-28 member states in GHG emissions, particularly in 2018, it appears that Lithuania recorded significant decline of about 57% in GHG emissions. This is followed by a 54% decline in Latvia and 53% decline in Romania. A substantial increase of about 23, 12, 11 and 11% were recorded in Germany, France, Italy and Portugal, respectively (see Table 1). While on the other hand, compared to 1990 statistics, an enormous increase was recorded in Portugal with about 19%, Spain with 20% and Cyprus with 54%, respectively. In addition, based on the statistics presented (see Table 1), it appears the E-28 countries (or some of the member states) have achieved their set target of reducing GHG to zero or nearest minimum. According to the 'with existing measure' (WEM) and 'with additional measure' (WAM) scenarios where the former reflects the impacts of all approved and executed measures, and the latter, which takes into consideration the planning phase when the projections were drafted, the GHG emissions is expected to decline by 26 and 27% by 2020 and 30 and 32% by 2030 compared with 1990 statistics under each scenario.

Domestic material consumption (DMC) takes into consideration the sum of the materials used directly by a nation. It is the raw material extracted from a nation (local territory) by adding all physical imports and deducting physical exports. It provides (DMC indicator) a means of assessing the level of use of the available resources in a country, while distinguishing between consumption, which is export market-driven from those that are local demand-driven. The material resources that make up DMC in an economy according to Weisz et al. (2006) are biomass (in terms of food, feed, animals, wood and other biomass), fossil fuels (in terms of coal, oil, natural gas and other

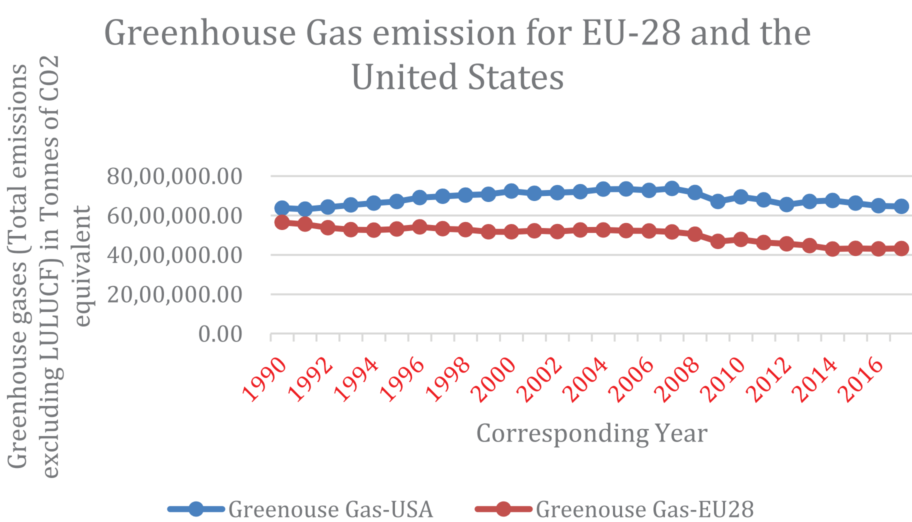

FIGURE 1 Graphical plot of GHG emissions trend for EU-28 countries (1990–2017).
Source: Organization for Economic Cooperation and Development [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 GHG emissions by countries in million tonnes of CO_2e (1990–2018)

	1990	1995	2000	2005	2010	2015	2018	Share in EU-27*
EU-27	4,911.6	4,626.5	4,543.4	4,647.1	4.3	3.9	3,893.1	100.0%
Belgium	149.6	157.4	154.4	149.9	0.1	0.1	123.6	3.2%
Bulgaria	102.5	75.5	59.8	64.7	0.1	0.1	58.6	1.5%
Czech Republic	199.6	158.5	151.2	150.0	0.1	0.1	129.4	3.3%
Denmark	72.6	80.5	73.6	69.3	0.1	0.1	51.3	1.3%
Germany	1,261.6	1,136.4	1,063.0	1,016.4	1.0	0.9	888.7	22.8%
Estonia	40.4	20.2	17.3	19.2	0.0	0.0	20.2	0.5%
Ireland	56.6	60.3	70.1	72.2	0.1	0.1	64.2	1.7%
Greece	105.8	112.0	129.0	139.1	0.1	0.1	96.1	2.5%
Spain	294.2	335.6	398.4	455.0	0.4	0.4	352.2	9.0%
France	556.9	553.7	567.2	570.7	0.5	0.5	462.8	11.9%
Croatia	32.4	23.0	25.9	30.2	0.0	0.0	24.4	0.6%
Italy	520.4	535.3	560.5	595.1	0.5	0.4	439.3	11.3%
Cyprus	6.4	7.9	9.3	10.2	0.0	0.0	9.9	0.3%
Latvia	26.6	13.1	10.6	11.6	0.0	0.0	12.2	0.3%
Lithuania	48.4	22.5	19.6	22.9	0.0	0.0	20.6	0.5%
Luxembourg	13.1	10.7	10.6	14.3	0.0	0.0	12.4	0.3%
Hungary	94.5	75.9	74.0	76.2	0.1	0.1	64.1	1.6%
Malta	2.8	3.0	3.1	3.2	0.0	0.0	2.7	0.1%
Netherlands	226.3	239.3	229.7	225.7	0.2	0.2	200.5	5.1%
Austria	79.4	80.7	82.0	94.4	0.1	0.1	81.5	2.1%
Poland	475.7	447.5	396.7	405.4	0.4	0.4	415.9	10.7%
Portugal	60.2	70.4	83.7	88.0	0.1	0.1	71.6	1.8%
Romania	248.8	187.9	143.6	151.8	0.1	0.1	116.5	3.0%
Slovenia	18.7	18.7	19.1	20.5	0.0	0.0	17.6	0.5%
Slovakia	73.6	53.4	49.3	51.4	0.0	0.0	43.5	1.1%
Finland	72.2	72.7	71.3	71.2	0.1	0.1	58.8	1.5%
Sweden	72.5	74.6	70.1	68.6	0.1	0.1	54.6	1.4%
United Kingdom	809.7	768.1	742.5	726.6	0.6	0.5	498.7	12.8%
Iceland	4.0	3.8	4.6	4.5	0.0	0.0	6.2	0.2%
Lichtenstein	0.2	0.2	0.2	0.3	0.0	0.0	0.2	0.0%
Norway	52.1	52.2	56.0	56.3	0.1	0.1	53.8	1.4%
Switzerland	57.3	56.8	58.0	59.1	0.1	0.1	52.1	1.3%
Turkey	219.9	248.6	300.4	340.5	0.4	0.5	533.0	13.7%

Note: Data are reported in million tonnes of CO_2e and % share. * Indicates the total estimate is strictly an aggregate of the 27 EU states without the United Kingdom and Turkey.
Source: Eurostat European Environment Agency.

fossil fuels), industrial minerals (in terms of ores, industrial minerals) and lastly construction minerals (all minerals employed initially in construction). It will be theoretically right to assume that an increase in the extraction and consumption of these minerals resources, most especially fossil fuel by a nation, would have an immediate impact on the GHG emissions, hence environmental pollution degradation (Weisz et al., 2006). The consumption being referred to here is perceptible consumption and not final in any form. In this study, we focus on the impact that an increases or decreases in DMC (in aggregate) would have on the environmental degradation (GHG emissions).[2]

Over the past two decades ago, many studies (see Barbiero et al., 2003; Castellano, 2001; De Marco, Lagioia, & Mazzacane, 2000; Femia, 2000; German Federal Statistical Office–Statistisches Bundesamt, 1995 German Federal Statistical Office–Statistisches Bundesamt, 2000; Giljum, 2004; Hammer & Hubacek, 2002; Mäenpää & Juutinen, 2001; Isacsson, Jonsson, Linder, Palm, & Wadeskog, 2000; Machado, 2001; Muukkonen, 2000; Mündl, Schütz, Stodulski, Sleszynski, & Welfens, 1999; Pedersen & de Haan, 2006; Ščasný, Kovanda, & Hák, 2003; Schandl & Schulz, 2002) have examined what make up material flow account for different economies in various geographical regions while some of the studies conducted cross-country analysis (see Adriaanse et al., 1997; Bringezu, Schütz, & Moll, 2003; Bringezu, Schütz, Steger, & Baudisch, 2004; Eurostat, 2001; Eurostat, 2002; Fischer-Kowalski & Amann, 2001; Matthews et al., 2000). The studies listed above, which either applied time series analysis or cross-country, majorly focused on the components, difference in material resources and determinants of domestic material consumption. This current study appears to be among few (if any) to examine the role of domestic material consumption on GHG emissions while controlling for renewable energy consumption and real income for the EU-28 countries.

Following the given background, this current study seeks to examine how consumption and production activities have contributed to an increase/decrease in GHG emissions, particularly within the EU-28 countries over the sample periods. In this study, the consumption pattern is measured by the per capita domestic material consumption while renewable energy consumption and economic growth (real GDP per capita), respectively, capture the influence of cleaner energy development and income on GHG. Thus, the main objective of this study is to examine the impact of domestic material consumption, renewable energy consumption and economic growth on GHG emissions, and its implications for environmental targets within the context of EU-28 countries and the world economies at large.

The contribution of this study is as follows: First, this study is among a few studies that examined the role and impact of domestic material consumption of GHG emissions, and the implication for environmental sustainability targets, especially for the EU-28 member states, using an econometric analysis. Policy insights that would be driven from this study would help the governments, policymakers and the body of knowledge at large. Understanding how to create a balance between consumption pattern and production activities would indeed help policymakers to make sound and effective environmental policy decisions that would help to address environmental pollutions caused by human activities and thus promote healthy and sustainable environment for the present and future generations. Second, we make use of the pooled mean group (PMG) of the autoregressive distributed lag (ARDL) model as proposed by Pesaran, Shin, and Smith (1999). The PMG-ARDL approach is relevant for this study because it simultaneously provides the short- and long-term estimates for a panel-based study. Third, empirical results suggest that a rise in the emissions of greenhouse gases is a direct consequence of an increase in consumption of domestic materials, and that domestic material consumption is not environmental friendly in the EU-28 countries. Lastly, from a policy standpoint, our finding revealed that real GDP causes greenhouse gas emissions, which is a signal to discourage excessive utilisation of fossil fuels through raising taxes on pollutant activities and motivate the consumption from clean energy sources such as wind, waste, hydroelectric, biomass, solar and geothermal.

The remainder of this study is scheduled as follows: Section 2 gives details about data and empirical method adopted, Section 3 is about the result and discussion of the findings and Section 4 concludes the study with policy recommendations.

2 | DATA AND EMPIRICAL METHOD

2.1 | Data

In the current study, we employed the panel data of 28 European Union member countries over the experimental period of 2000–2017. The dataset employed comprises: the Gross Domestic Product per capita (GDPC, measured by constant 2010 USD [United States Dollars]), the Domestic Material Consumption per capita (DMCC, the amount of material used domestically in an economy and is measured in tonnes), the share of renewable energy consumption per capita (RENEC, is the per capita contribution of renewable energy to the overall primary energy supply and measured in thousand tonnes of oil equivalent) and the total greenhouse gas emissions per capita (GHGC, major greenhouse gases and emissions from man-made and measured in thousand tonnes of CO_2 equivalent). The series DMCC was retrieved from the OECD (Organization for Economic Co-operation and Development, 2019) while GDPC was retrieved from the World Bank Development Indicator, 2019). In the case of the renewable energy consumption and greenhouse gas, the series were retrieved from the WDI but updated by the European Commission (EC) statistics (Eurostat, 2020). Moreover, the GHGC is explored as the dependent variable while the other variables (GDPC, DMCC and RENEC) are the explanatory variables.

From Table 2, the statistical description of the series is presented. Given these statistical properties, the largest variance is observed in the GHGC series followed by the GDPC, RENEC and the DMC. Furthermore, the series are positively skewed (evidence from the positive values of the skewness) while the kurtosis presents a significant evidence of peakness as the kurtosis for all the series are greater than 3.

2.2 | Empirical method

2.2.1 | Model

In earlier studies, consumption patterns among other socio-economic, environmental, behavioural and cultural practices are consistently

TABLE 2 Statistical properties of the series

	GHGC	GDPC	DMCC	RENEC
Mean	0.011	31,702.84	16.191	3.69E-06
Median	0.001	27,798.23	15.645	1.58E-06
Maximum	0.029	111,968.3	34.829	2.09E-06
Minimum	0.005	3,955.276	1.776	1.44E-06
SD	0.004	20,851.56	5.915	4.70E-06
Skewness	1.821	1.386	0.505	1.792
Kurtosis	7.442	5.761	3.974	5.798
Observations	504	504	504	504

Note: The statistical significance at 1, 5 and 10% levels are, respectively, represented as a, b and c. In addition, the GHGC, GDPC, DMCC and RENEC are, respectively, presented as the Greenhouse gas, Gross Domestic Product per capita, Domestic Material Consumption per capita and the renewable energy consumption.

being linked with environmental degradation (Apergis & Ozturk, 2015; Auci & Vignani, 2014; Cop, Alola, & Alola, 2020; Dogan & Ozturk, 2017; Ibrahim & Alola, 2020; Kim, 2002; Wang, Wang, Du, Li, & He, 2020). By expanding related studies on environmental sustainability in the EU (Gardiner & Hajek, 2020), the environmental effect of per capita of domestic material consumption and income in addition to the renewable energy utilisation in the panel of EU-28 is model as follows:

$$GHGC = f(GDPC, DMCC, RENEC) \tag{1}$$

where the GHG accounts for the environmental degradation and upon the logarithmic transformation of the model, the functional form is now presented as follows:

$$LGHGC_{i,t} = \phi_0 + \phi_1 LGDPC_{i,t} + \phi_2 LDMCC_{i,t} + \phi_3 RENEC_{i,t} + \varepsilon_{i,t} \tag{2}$$

where ϕ_0 is the constant of the panel estimate and ϕ_1, ϕ_2, ϕ_3 are the respective environmental degradation (GHG) effect of GDPC, DMCC and RENE. ε is the error term for every cross-section i (i = 1, 2, …,28) and year period t (t = 2000, 2001, …, 2017).

2.2.2 | Empirical approach

Considering the series are stationary at most after the first difference and the evidence of co-integration as implied in Table A1 of the appendix, respectively, the appropriateness of the PMG of the ARDL model is employed. As opined by Pesaran et al. (1999), the PMG-ARDL approach is considered relevant for this study because it simultaneously provides the short- and long-term estimates. This is in addition to the fact that the PMG approach permits the experimentation with different lags for both the independent and dependent variables. In Equations (3) and (4), the homogenous long-run coefficients and heterogeneous short-run coefficients estimation procedures across the cross-sections are, respectively, presented from the PMG-ARDL approach.

$$LGHGC_{i,t} = A_i + \sum_{j=1}^{p} B_{i,j} LGHGC_{i,t-j} + \sum\nolimits_{j=0}^{q} C_{i,j} X_{i,t-j} + \varepsilon_{i,t} \tag{3}$$

such that $A_{i,j}$ is cross-sectional effects and both $B_{i,j}$ and $C_{i,j}$ are the coefficients to be estimated. Also,

$$\begin{aligned} &\Delta LGHGC_{i,t} \\ &= \phi_i LGHGC_{i,t-1} - \partial_i X_{i,t} + \sum_{j=1}^{p-1} \varphi_{i,j} \Delta LGHGC_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \lambda_{i,j} \Delta X_{i,t-j} + \varepsilon_{i,t} \end{aligned} \tag{4}$$

where i and t are the cross-section and year period, respectively. The adjustment parameter/speed of convergence (also known as the error correction term, ECM (ϕ_i) and the long-run coefficients (∂_i) are estimated from the first part of the expression $\phi_i LGHGC_{i,t-1} - \partial_i X_{i,t}$ of Equation (4) while the other part of the right-hand side illustrates the estimate of the short-run. In general, X shows the vector of the explanatory variables, i.e., GDPC, DMCC and RENEC). The estimates for the long run and short run from the indicated PMG-ARDL approach are detailed in Table 3.

2.2.3 | Additional Estimates

In addition to the cross-section short-run estimates in Table 3, for policy perspectives, a diagnostic test that examines the Granger causality between the variables is also implemented. In this case, we apply the Dumitrescu and Hurlin (2012) heterogeneous panel causality test (hereafter D-H). Consider that the heterogeneity and CD in the panel data are prioritised by the test approach, thus it is considered a superior technique to other causality tests. Accordingly, the estimation procedure of this Granger causality approach is provided in the extant literature (Dumitrescu & Hurlin, 2012), and the result is illustrated in Table 4.

3 | RESULTS AND DISCUSSION

The first part of the estimation illustrates the environmental degradation effect of income, domestic material consumption per person and the renewable energy utilisation (see Table 3). İn this case, the PMG-ARDL estimated result posits that a 1% increase in consumption of domestic material individually in the panel of EU-28 states is responsible for the increase in the emissions of greenhouse gases by 0.144% in the short-run. This simply implies that the immediate effect of the (domestic) consumption patterns of the EU-28 member countries is not environmental friendly. Evidently, the result posited by Kim (2002) and Auci and Vignani (2014) motivates the evidence in the current context. In a similar situation, there seems to be no improvement in the environmental quality in the long run. In the long term, there is statistical significance evidence that consumption of domestic materials is equally responsible for an increase in the greenhouse gas emissions. Thus, this suggests an awakening concerning the projection of the EU-28 member states, especially attaining a sustainable domestic material consumption.

The evidence of the environmental effect of domestic material consumption in the short and long run is not unconnected with the country-specific patterns of domestic material consumption. For instance, domestic material consumption is responsible for a significant increase in the emissions of greenhouse gases, especially in the short-run in 19 of the 28 EU member states (Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Romania, Slovakia, Slovenia, Spain and Sweden). Although the Nordic countries (such as Denmark, Finland and Sweden) are believed to have progressed in achieving the 17 sustainable development goals (SDGs), their specific effort towards the SDG 12 (attaining a sustainable consumption and production [SCP]) has been poorly ranked (Sustainable Consumption and Production, 2018). The result further shows that the domestic

TABLE 3 PMG-ARDL estimate

Estimate	LGDPC	LDMCC	RENEC	ECT (−1)
Panel long-run	−0.059[A]	0.103[A]	−66,241-90[A]	
Panel short-run	0.225[B]	0.144[A]	−260,307.9	−0.290[A]
Cross-section (short-run)				
Austria	0.015	0.341A	87,411.73	
Belgium	−0.385	0.268[A]	43,023.97[A]	−0.27[A]
Bulgaria	0.104	0.137[A]	−139,947	−0.12[A]
Croatia	0.375[A]	−0.027[B]	−38,507.34	−0.12[A]
Cyprus	−0.682	0.465[C]	−33,007.71	−0.23[B]
Czech Republic	0.457[A]	0.108[B]	−127,092.5	
Denmark	1.259[A]	−0.317[A]	−19,665.29	
Estonia	1.259[C]	−0.122	18,886.33	−0.07[A]
Finland	−0.672	0.868[B]	−43,281.9	
France	0.111	0.261	637,881.8	−0.02[B]
Germany	−0.297[A]	0.188[A]	−568,124.4	−0.28[A]
Greece	0.596[A]	0.168[B]	−185,502.5	−0.44[C]
Hungary	0.741[A]	0.096[A]	−51,639.16	
Ireland	−0.040[B]	0.203[A]	−98,488.25	−0.13[A]
Italy	0.319[A]	0.469[A]	535,533.6	−0.30[A]
Latvia	−0.385[B]	0.377[A]	−18,050.42	−0.07[A]
Lithuania	−0.308	0.476[A]	−43,147.31	−0.07[A]
Luxembourg	−0.024	−0.026[A]	−4,923.36	−0.03[A]
Malta	−0.454	0.348[A]	7,008.31	−0.07[A]
Netherlands	1.237[A]	−0.480[A]	−50,420.25	−0.26[A]
Poland	1.303	−0.178	−85,966.92	−0.29[A]
Portugal	0.930	0.040	−104,795.4	−0.46[A]
Romania	0.034[A]	0.150[A]	−334,797.7	−0.68[A]
Slovakia	0.137[B]	0.065[A]	−16,999.55	−0.16[B]
Slovenia	0.329[A]	0.092[A]	13,006.10	−0.02[A]
Spain	−0.563[A]	0.440[A]	−292,592.8	−0.15[A]
Sweden	0.587[A]	0.076[A]	−109,152.6	−0.13[A]
United Kingdom	−0.023	0.069	−6,239,267	

Note: The 1, 5 and 10% statistical significant levels are, respectively, presented as [A], [B] and [C].

material consumption improves the environmental quality in 4 of the 28 EU member states (Croatia, Denmark, Luxembourg and Netherlands). Although the impact of per capita domestic material consumption is desirable in Estonia and Poland, there is no significant evidence. İn the case of France, Portugal and United Kingdom, the environmental effect of domestic material consumption is not desirable.

Furthermore, the per capita share of renewable energy consumption in the panel of the EU-28 has a significant and desirable environmental effect in both the short and long run. İn the extant literature, alternative energy sources have been significantly linked with emission mitigation or low-emission policy and carbon actions of the region (Alola, Yalçiner, Alola, & Saint Akadiri, 2019; Alola, Bekun, & Sarkodie, 2019; Akadiri et al., 2019; Bekun, Alola, & Sarkodie, 2019; Adedoyin, Alola, & Bekun, 2020; de Llano-Paz, Calvo-Silvosa, Antelo, & Soares, 2015; Doğan, Driha, Balsalobre Lorente, & Shahzad, 2020; Su, Wang, Streimikiene, Balezentis, & Zhang, 2020). In addition, income per head in the panel examination displays a differing effect in the short- and long-run. In specific, the long-run effect of real GDP per capita is negative, inelastic and significant while its short-run effect is positive, inelastic and statistically insignificant. This result implies that when income level per person increases by 1%, GHG emission per person tends to decrease by about 0.06% in the long-run and increases by about 0.23% in the short run. Therefore, it is safe to posit that both low-emission consumption and technology effects outweigh the scale effect in the long-run while the opposite is true in the short run. Concerning country-specific account, the results are quite mixed and interesting because of the heterogeneous effect of economic

TABLE 4 Granger causality

Null hypothesis	W-Stat.	Zbar-Stat.	Prob.
GDPC does not Granger cause GHG[A]	8.735	7.615	3.E-14
GHGC does not Granger cause GDPC	2.454	0.017	0.987
DMCC does not Granger cause GHG[A]	5.399	4.631	4.E-06
GHGC does not Granger cause DMCC[A]	6.570	7.493	7.E-14
RENEC does not Granger cause GHGC	2.247	−0.335	0.738
GHGC does not Granger cause RENEC[A]	4.826	4.038	5.E-05
DMCC does not Granger cause GDPC[B]	3.718	2.160	0.031
GDPC does not Granger cause DMCC[A]	6.056	6.124	9.E-10
RENEC does not Granger cause GDPC	3.200	1.281	0.200
GDPC does not Granger cause RENEC[A]	7.455	8.496	0.0000
RENEC does not Granger cause DMCC[A]	4.105	3.306	0.001
DMCC does not Granger cause RENEC[B]	3.923	2.122	0.034

Note: The 1, 5 and 10% statistical significant levels are, respectively, presented as [A], [B] and [C].

conditions. Only in countries such as Germany, Ireland, Latvia and Spain the effect of real GDP per capita is negative, which suggests that an increase in the income level of the people mitigates environmental degradation. The possible reason behind the result is that as people's wealth increases, they become more aware and committed to environmental protection. Although this desirable outcome is peculiar to 4 of the 28 EU member states, the result echoes the study of Bouvier (2004) and Caron (2020). Moreover, the finding is congenial with Usman, Alola, and Sarkodie (2020)Usman, Akadiri, and Adeshola (2020) who found economic growth to exert negative pressure on environmental degradation in the United States.

The results of the causality based on the heterogeneous panel causality test indicate that a uni-directional causal relationship runs from GDPC to GHG. The causality between DMCC and GHG has a feedback effect, while GHG is found to Granger-cause RENE. Furthermore, we find evidence that the causal relationship between DMCC and GDPC as well as RENE and DMCC is bidirectional. İn other words, a feedback effect is found not only in the causal relationship between DMCC and GDPC but also between RENE and DMCC. However, GDPC is found to Granger-cause RENE. The result that GDPC aggravates GHG emission is consistent with the earlier finding of Usman, Iorember, and Olanipekun (2019) that economic growth predicts environmental degradation in India.

4 | CONCLUSIONS AND POLICY IMPLICATION

This study uses 28 European Union countries to investigate the effect of real gross domestic product per capita, domestic material consumption per capita and renewable energy consumption on greenhouse gas emissions over the experimental period of 2000–2017. The empirical results suggest that in the short run, 0.144% rise in the emissions of greenhouse gases is a direct consequence of an increase in per capita consumption of domestic materials. This implies that domestic material consumption is not environmental friendly in the EU-28 countries, especially over a short period. Although the negative impact of per capita domestic consumption is lesser in the long run, more GHG emission is yet accounted for due to their consumption pattern. In specific, a 0.103% rise in greenhouse gas emissions is attributed to a 1% increase in domestic material consumption per capita. The accounts of the short-run country-specific cases revealed that per capita consumption of domestic materials impedes environmental quality in 19 out of the 28-EU member countries while improves environmental quality in 4 out of 28-EU countries. Moreover, renewable energy consumption exhibits environmentally desirable (mitigation) effect on greenhouse gas emissions in both long run and short run, respectively, in the panel estimations. Finally, real GDP per capita is positively associated with greenhouse gas emissions, especially in the immediate period. However, the panel result reveals that the improvement in the income level is significantly capable of producing a greenhouse gas mitigating effect in the long run. Notwithstanding, the effect of the real GDP per capital on the basis of country-specific is positive in most of the countries due to heterogeneous economic conditions in the sample countries. The few cases where the effect of real GDP per capita is negative suggest the consciousness of the people and government about environmental improvement. Furthermore, the results of the causality support bidirectional type between domestic material consumption per capita and greenhouse gas emission, domestic material consumption per capita and real GDP per capita, as well as renewable energy consumption and domestic material consumption per capita. We also find that real GDP per capita causes greenhouse gas emissions and renewable energy consumption while real GDP per capita is found to predict greenhouse gas emissions.

The policy implication for our finding is mainly focused on the consumption pattern in the examined panel countries. The governments of the EU countries should further focus on policy that addresses the consumption and technology effect. Such policy could directly alter the trajectory pattern of conventional energy utilisation and energy intensity, thereby improving countries' profile of energy efficiency. Considering the desirability of the consumption and technology effect, the EU economies can achieve more environmental sustainability progress by improving the income level of the people. A desirable effect of consumption of domestic materials along with an increase in the income level could largely be achieved across the region through a sustained environmental management and awareness programme. Moreover, the findings of this study further canvass for an increased share of renewable energy in the consumption of material resources as a surest and effective policy to address environmental pollution and achieve sustainable environmental improvement.

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ENDNOTES

[1] There has been a shift from non-renewable energy sources of production by some of these advanced nations (e.g., France, United State, Singapore, United Kingdom among others) to a more environmental friendly (renewables) energy sources that emit little or no carbon emissions and promote energy-saving and energy-efficient technology in order to curb environment pollution/degradation (carbon dioxide emissions).

[2] To understand what makes up DMC interested, the reader can see the following Weisz et al. (2006), Bringezu and Schütz (2012), Eurostat (2001) among others.

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APPENDIX

TABLE A1 The unit root and co-integration tests

Unit root test	LLC Level	LLC Δ	Im, Pesaran Shin Level	Im, Pesaran Shin Δ
LNRGDPC	−1.055	−8.722[A]	1.833	−6.185[A]
LNGHGC	−1.995	−9.447[A]	0.866	−10.600[A]
LNDMCC	−2.700[B]	−9.343[A]	0.053	−8.233[A]
LNRENEC	−1.222	−6.105[A]	3.406	−6.318[A]

Pedroni residual co-integration test

Newey–West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: Common AR coefficients (within-dimension)

	Statistic	Prob.	Weighted Statistic	Probability
Panel v-Statistic	−0.551	0.709	−0.964	.833
Panel rho-Statistic	−0.261	0.397	−0.026	.490
Panel PP-Statistic	−7.334	0.000[A]	−7.507	.000[A]
Panel ADF-Statistic	−3.009	0.001[A]	−3.836	.000[A]

Alternative hypothesis: Individual AR coefficients (between-dimension)

	Statistic	Probability
Group rho-Statistic	2.043	0.980
Group PP-Statistic	−10.390	0.000[A]
Group ADF-Statistic	−2.475	0.007[A]

Note: The superscripts [A] and [B], respectively, indicate 0.01 and 0.05 statistical rejection while Δ represents first difference. The fitted model for the unit root accounts for both individual intercept and trend. The study applied the Levin, Lin and Chu (2002) unit root test which is denoted by LLC and Im, Pesaran and Shin (2003) unit root test.