The Environmental Efficiency-Export Performance Nexus: Fresh Evidence from the Top Environmental Performance Index (EPI) Countries

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The Environmental Efficiency-Export Performance Nexus: Fresh Evidence from the Top Environmental Performance Index (EPI) Countries

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Abstract

The quest for sustainability and greener economies has intensified the call for more stringent environmental regulation, hence environmental efficiency of production processes that produce growth. Since trade activities represent a huge part of economic growth, while countries are becoming increasingly cautious of their imports, environmental efficiency becomes an integral consideration for trade. This study investigates the link between environmental efficiency and export performance among the top 20 countries on the environmental performance scale utilizing annual data between 1980 and 2019. The classic comparative advantage theory of international trade provides the theoretical basis for the study. Environmental efficiency scores were generated using the slack-based data envelopment analysis while the nature of causality between environmental efficiency and export performance is established using the Pairwise Dumitrescu Hurlin Panel Causality Tests and VECM Granger causality approaches. The export models are estimated using the fully modified and dynamic ordinary least squares approaches.

Bidirectional causality is found between export per capita (and export intensity) and environmental efficiency for the panel analysis. Causality results is however mixed at country level with significant unidirectional causal links running from either export to environmental efficiency or otherwise. The FMOLS and DOLS analysis provides evidence of significant positive effect of environmental efficiency on export per capita and export intensity for the panel of the top EPI countries, and confirmed in most of the countries. The study therefore provides strong evidence for the role of environmental efficiency in countries' efforts to improve their global competitiveness in trade-related activities. Thus, the study emphasizes increased global investment in environmental efficiency as the global economies grow.

Keywords: Environmental Efficiency; Export Performance; EPI Countries; Data Envelopment Analysis

JEL: F18; Q56; Q58; N40

1.0 Introduction

The rate of globalization in the past few decades has been tremendous, engendering economic growth and enhancing knowledge spillover across countries. The production of growth however, has attendant environmental implications, which raises serious concerns for sustainable growth and development through the various associated economic activities (Awodumi and Adewuyi, 2020). As countries become conscious of the health and environmental implications of their production and consumption activities, which can be significantly influenced by the increased global trade, protecting national boundaries against unhealthy products has become a top priority among governments and policymakers. The Kyoto Protocol of 1997 encouraged countries, especially the developed economies, to set environmental targets and tightened environmental regulations, including Trade-Related Environmental Measures (TREMs) and Environment-Related Trade Measures (ERTMs) to promote environmental quality. The World Trade Organization (WTO) recognized the adverse implication of this development on trade, warning countries not to turn environmental policies into technical barriers that retard trade (WTO, 2014). Consequently, environmental efficiency, through the adoption of environment-friendly techniques, promotes clean production processes which become an integral consideration for international competitiveness.

A recent debate among researchers and policymakers is whether improvement in environmentally efficiency of production processes promote international competitiveness, and whether the goal of increasing global trade share matter for this efficiency. A conscious investment in environmental quality, through stringent environmental regulations, has direct implication for production costs both in the short-run and the long-run. Adopting environmentally efficient production techniques tends to generate initial short-run costs that outweigh benefits to firms, thus retarding productivity and export. In the long-run, reduction in cost per unit of output manifest in the form of healthy working environment, healthy workforce, and reduction in externality and associated tax. This raises output per unit of environmental pollution that produce greater benefits than costs to firms, with the greater tendency to produce clean goods for export which enhances comparative advantage of the country (Doganay et al, 2014). On the other hand, as countries seek to penetrate more market, and meet environmental standards and regulations in the importing countries, they tend to raise the environmental requirements for their exports. This may underscore the continuous investment in environmental efficiency and quality in most advanced countries, who constantly raise the level of their environmental performance.

A number of countries have been successful to a large extent in adopting innovative policy measures to improve the various aspects of environmental health outcomes as well as ecosystem vitality. These countries are highly committed to air quality improvement and climate change mitigation, especially reduction in carbon emission. For instance, despite the increased economic activities, growth and income among the top countries on the Environmental Performance Index (EPI Top 20 henceforth), environmental pollution associated with production and consumption activities has been reduced significantly. Among these countries, average real output per capita rose by over 80% between 1980 and 2019, whereas carbon emissions per capita dropped by almost 20% since 1980 and 30% since early 2000s. During the same period (1980-2019), carbon emission per output and carbon intensity of energy continues to decline, which may indicate the use of environment-friendly production schemes that tends to improve environmental efficiency. This development appears to be favourable for exports as real exports and its intensity rose steadily and significantly between 1980 and 2019, recording a growth of over 400% and 80% respectively, though the direction of influence remains unclear.

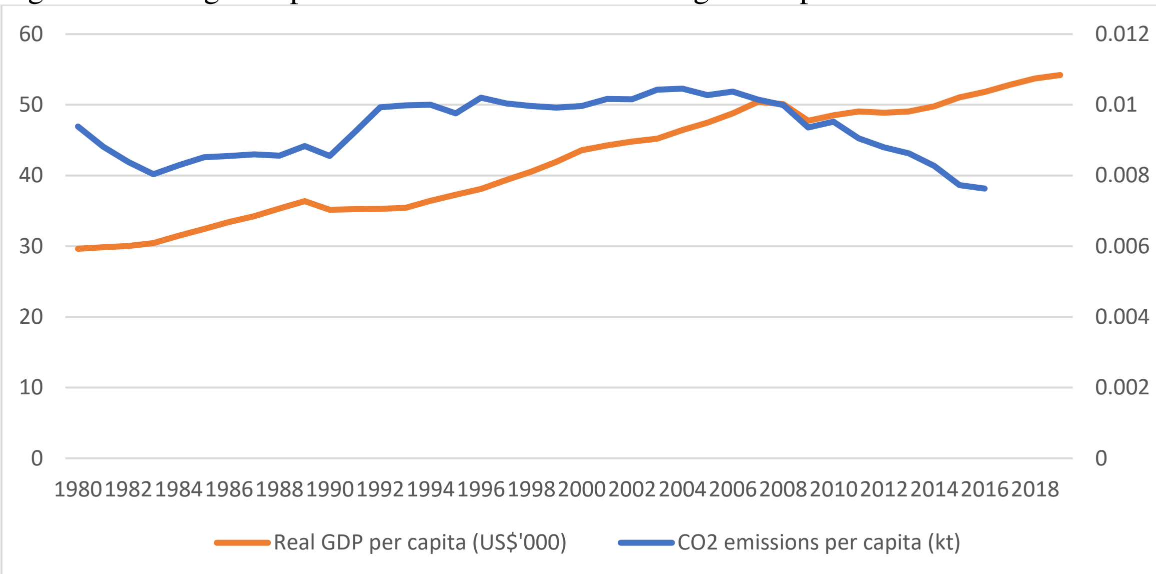
The foregoing raises key policy issues: what causal relationship exist between environmental efficiency and export performance? Does environmental efficiency matter for export performance? Does the influence and direction of causality differ across the EPI Top 20 countries? Answers to these questions are pertinent for environmental and trade policy design and implementation, both in the industrialized and developing economies. This study therefore investigates the link between environmental efficiency and export performance among the top 20 EPI countries.

The debate on the role of environmental efficiency on export performance is relevant for national and international policymakers in developing, emerging and advanced economies who seek to expand their share of export markets. The study particularly provides evidence and lessons from top countries who have successfully investment in environmental quality for other countries, such as natural resources-endowed economies, where there are increased calls for export diversification and greater contribution to Global Value Chains (GBVs). Existing studies concentrate on the role of environmental regulation (policy variable) in trade (Costantini and Crespi 2008, and Hering and Poncet 2014), rather than environmental efficiency which represents the outcome of the various policy efforts. Moreover, while Doganay et al, (2014) considered environmental efficiency, it ignores specific cases, as it analyzed bilateral trade for a panel of 111 countries, irrespective of their level of environmental commitment and performance.

2.0 Export, Output and Carbon Emission Among the Top 20 EPI Countries

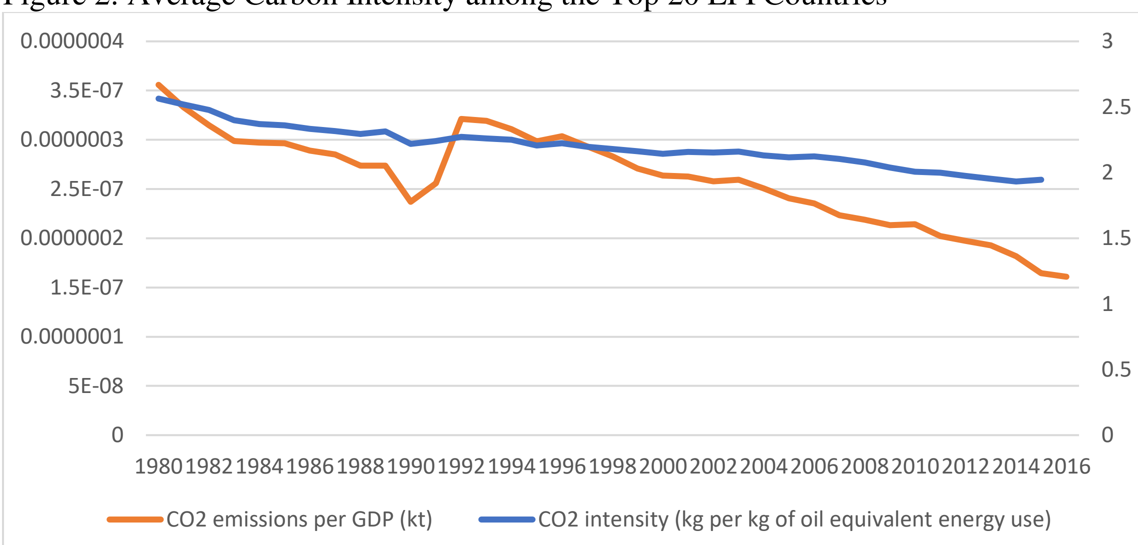
The highest ranked countries on the EPI scale have been largely successful in reducing the environmental implication of their production and consumption activities, especially in terms of greenhouse gas. Unlike most other countries experiencing sustained economic growth overtime, the top EPI countries, average carbon emissions declined significantly over the last two decades. For instance, average real per capita output in these countries increased from about $30,000 in 1980 to $54,000 in 2019, growing by about 80% during this period, following minor distortions in the late 1980s to early 1990s, and the late 2000s (Figure 1). Despite this growth performance, average carbon emissions per capita, which initially followed upward trend between 1983 and early 2000s, fell by over 30% between 2004 and 2019. This indicates the increasing investment in and utilization of alternative energy, especially from renewable sources, to power growth. The top EPI countries have also proved to be successful adopters of environment-friendly production techniques including carbon-reducing technologies. Average carbon intensity of both output and energy fell noticeably between 1980 and 2019 as indicated in Figure 2. This reflects the general shift away from the use of fossil fuel (oil, gas and coal) in industries among these countries as they evolve as green economies. The implication of this environmental performance on trade relations of these countries with their partners becomes pertinent.

Figure 1: Average Output and Carbon Emission among the Top 20 EPI Countries



Source: Author's Contribution, Data from the World Band World Development Indicators

Figure 2: Average Carbon Intensity among the Top 20 EPI Countries

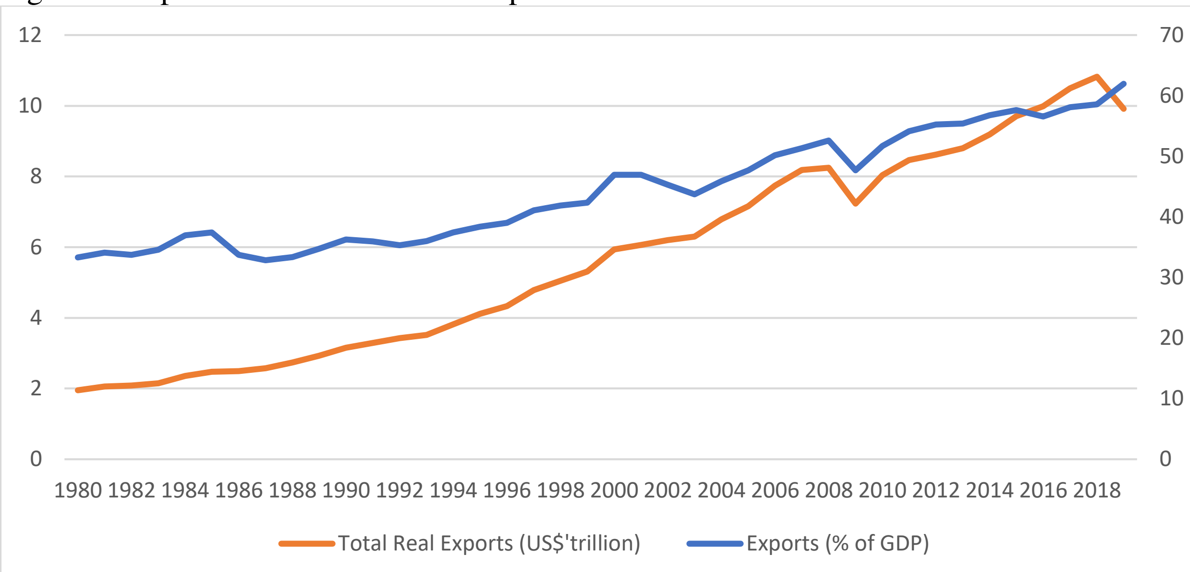


Source: Author's Contribution, Data from the World Band World Development Indicators

Trade is a major economic activity in many countries which continues to spur economic growth globally. In particular, exports evolve as an important contributor to the national output of the countries that have performed excellently on the environmental performance index. As shown in Figure 3, total real exports among the top 20 EPI countries rose significantly from about \$2 trillion in 1980 to \$10.8 trillion in 2018, representing over 400% increase over the period. The share of exports in total gross domestic product among these countries followed similar trend, rising from

33% in 1980 to over 60% in 2019. As much as economic growth enhances the capacity to export and provides the conducive environment for the production of export, the latter in turn plays a major role in improving the economic performance of the top EPI countries.

Figure 3: Export Performance of the Top 20 EPI Countries



Source: Author's Contribution, Data from the World Band World Development Indicators

3.0 Review of Literature

Empirical literature on the relationship between environmental quality and international trade is still developing both at the single-country and cross-country levels. Most studies only focused on the analysis of the effect of environmental regulation (policy variable) on international trade, rather than environmental efficiency (policy outcome variable) (van Beers and van den Bergh 2000; Cole and Elliott 2003; Costantini and Crespi 2008, and Hering and Poncet 2014). One strand of the literature argues in favour of the positive contribution of environmental standards to international competitiveness by encouraging innovations and improving efficiency among exporting firms. This is evident in Doganay et al, (2014) who conducted a two-stage analysis of the impact of environmental efficiency on international trade during 1980-2009. Adopting ordinary least square (OLS) and general methods of moments (GMM) techniques for a panel of 111 countries, they found that environmental efficiency exerted positive effects on exports. Focusing on 14 OECD countries, van Beers and van den Bergh (2000) examined the effect of environmental policy on foreign trade using ordinary least square and Tobit technique, and discovered that strict environmental policy yielded increasing effect on total exports. Focusing on export dynamics of energy technologies for renewable energies during 1996-2005, Costantini and Crespi (2008) reported used panel OLS and revealed that environmental regulation significant promote such exports among 20 exporting and 148 importing countries. Costantini and Mazzanti (2012) revealed that specific energy tax policies, innovation efforts and environmental policies promoted EU export flows dynamics and green exports during 1996-2007 period.

The other strand of the literature presents argument that environmental regulation hinders international competitiveness as green protectionism may discourage innovation especially in the short-run. In line with this, Hering and Poncet (2014) estimated panel OLS model for the case of China and reported that stricter regulations on sulfur di oxide (SO_2) emissions had reducing impact on sectoral exports of more polluting industries between 1997 and 2003. Mulatu et al (2004) employed similar methods in the analysis of manufacturing industries in Germany, Netherlands and USA. They showed that stringency of environmental regulation accounted for the observed comparative disadvantage in dirty industries in the U.S. and Germany but only in the wood and fabricated metal industries for the case of the Netherlands with sectorial variation. In the same vein, Du and Li (2019) discovered that environmental regulation in China serves as a restraint for export-extensive and -intensive margin during the 2000-2011 period, with stronger negative effect on pollution-intensive enterprises than clean ones. For the same country, Deng et al (2021) showed that pollution reduction targets are detrimental to export product quality, especially for western regions, capital-intensive industries, privately owned firms and firms exporting to non-OECD countries.

Some studies however could not establish significant influence of environmental quality on export. This is evident in Cole and Elliott (2003) who used two stage least square technique to show no significant effect of environmental regulation on dirty goods exports among 60 developed and developing economies in 1995. Xu (2000) employed maximum likelihood method and also reported that more stringent environmental regulation does not reduce total exports, exports of environmentally sensitive goods (ESGs) and exports of non-resource-based environmentally sensitive goods (ESGs) among 20 countries. Similarly, Harris et al, (2002) reported negligible influence of relative strictness of environmental regulation in the exporting country on total export volume. Sakamoto and Managi (2016) demonstrated that energy and environmental efficiency are sources of comparative advantage in industries. In a panel regression analysis, they further reveal that the effect of environmental efficiency on export performance is small, especially in relatively less footloose industries. Adewuyi and Awodumi (2021) reported that higher carbon emissions tend to reduce petroleum imports in Nigeria but raised such import in South Africa between 1981 and 2015.

The review of literature shows that the influence of environmental related factors on trade has been explored both at cross county and single country levels. The literature also appears to focus on environmental regulation while ignoring the outcome of such regulation and its implication for export. More importantly, Doganay et al, (2014), which provided a role for environmental efficiency in bilateral trade, focused on cross country analysis of 111 countries irrespective of their environmental performance or commitment to climate change mitigation. This limits the strength of the study in terms of policy implication and lessons for different countries as they seek to improve their commitment to environmental quality and enhance export performance. Besides, different markets may require different levels of environmental standards for their imports. Despite the peculiarity of the green economies, environment-trade literature continued to ignore them. These are the gaps the present study seeks to fill with the purpose of eliciting lessons for different economies.

4.0 Theoretical Framework and Methodology

Theory and Model

Environmental efficiency improvement has important implications for comparative advantage patterns, hence international trade among countries. The study therefore explores the classic comparative advantage theory of international trade which emphasizes the relative costs of production as the main driver of specialization and export. Environmental costs are key elements of production cost basically informed by regulations and awareness (Doganay et al, 2014). In the short-run, regulation, such as emission tax which aims to improve efficiency, tends to increase environmental costs as the initial cost of compliance and acquiring environmentally efficient technology may be relatively high, raising costs and reducing comparative (cost) advantage and export in the process. Over the long-run, reduction in environmental costs largely results from the application of environment-friendly production schemes, and it is equivalent to improvements in environmental efficiency. This enhances comparative advantage and improves export performance.

Environmental efficiency therefore creates comparative advantage which is a key factor in export performance. Following Cole and Elliott (2003), Mulatu et al (2004) and Doganay et al (2014), export performance is specified as a function of environmental efficiency. Other variables such as, gross domestic product per capita (GDPPC), exchange rate (EXCH), Labour (LAB) and physical capital (PCAP) are controlled for.

$$X = f(EFF, INF, GDPPC, KGDP, LAB, PCAP) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where X and EFF are exports and environmental efficiency respectively. Export per capita (EXPPC) and share of export in GDP (export intensity-EXPGDP) are the two indicators utilized to measure export performance. Thus, Equation is re-specified in econometric form for each model for the individual country:

$$EXPPC_{it} = \beta_0 + \beta_1 EFF_{it} + \beta_2 INF_{it} + \beta_3 GDPPC_{it} + \beta_4 EXCH_{it} + \beta_5 PCAP_{it} + \beta_6 LAB_{it} + \varepsilon_{it} \ldots\ldots\ldots 2$$

$$EXPGDP_{it} = \theta_0 + \theta_1 EFF_{it} + \theta_2 INF_{it} + \theta_3 GDPPC_{it} + \theta_4 EXCH_{it} + \theta_5 PCAP_{it} + \theta_6 LAB_{it} + \mu_{it} \ldots\ldots 3$$

The same models are specified and estimated for the panel of countries:

$$EXPPC_{it} = \beta_0 + \beta_1 EFF_{it} + \beta_2 INF_{it} + \beta_3 GDPPC_{it} + \beta_4 EXCH_{it} + \beta_5 PCAP_{it} + \beta_6 LAB_{it} + \varepsilon_{it} \ldots\ldots\ldots 4$$

$$EXPGDP_{it} = \theta_0 + \theta_1 EFF_t + \theta_2 INF_t + \theta_3 GDPPC_t + \theta_4 EXCH_t + \theta_5 PCAP_t + \theta_6 LAB_t + \mu_{it} \ldots\ldots\ldots 5$$

First Stage Analysis

Two stages of analysis are conducted. The first stage computes environmental efficiency scores for each of the top 20 EPI countries using Data Envelopment Analysis (DEA). This study follows a production approach that differentiates between the disposability characteristics of environmentally desirable and undesirable outputs as suggested by Halkos and Tzeremes (2009) and Doganay et al (2014). The resulting environmental efficiency index indicates the amount of desirable output sacrificed in order to reduce the pollutant by one unit. Environmental efficiency is measured using non-parametric technique (data envelopment analysis-DEA) such that GDP represents the good (desirable) output while labour, capital and energy consumption serve as the input indicators to generate good efficiency. Similarly, carbon emission is utilized as the bad (undesirable) output, while the same inputs are used to complete the formulation for bad efficiency (Färe et al., 2003; Zaim et al., 2001; Zaim, 2004)[1]. The ratio of good efficiency to bad efficiency

[1] Carbon emission is selected due to its dominance as a measure of environmental quality in the environment-trade literature (Cristea et al, 2013; Doganay et al, 2014 and Honma, 2015).

gives the environmental efficiency ratio. Thus, higher ratio indicates higher environmental efficiency of producing a unit of output, which reduces the cost to more environmentally conscious producers. This is likely to improve the producers' comparative advantage. The slack-based DEA requires no mathematical functional form which makes it easy to compute, and it can also accommodate multiple inputs and outputs (Coelli et al., 2005).

The study considers N number of countries representing the Decision Making Units (DMUs) ($n=1,\ldots, N$) and T periods ($t=1,\ldots,T$) using m inputs and s outputs creating a sample of $N\times T$ observations. An observation n in period t, (DMU_t^n) has an m dimensional input vector x_t^n = $(\mathrm{x}_{1t}^n, \mathrm{x}_{2t}^n, \ldots, x_{mt}^n)$ and an s dimensional output vector $\mathrm{y}_t^n = (\mathrm{y}_{1t}^n, \mathrm{y}_{2t}^n, \ldots, \mathrm{y}_{st}^n)$.

The constant returns to scale DEA cost minimization problem for DMU_{qt} is analyzed by solving the following linear programming problem;

Minimise θ_q *4*

Subject to:

$\sum_{j=1}^{n} \lambda j X ij \leq \theta X_{iq}$ $\quad i = 1, \ldots, m$ 5

$\sum_{j=1}^{n} \lambda j Y rj \geq Y_{rq}$ $\quad r = 1, \ldots, s$ 6

$\lambda j \geq 0$ $\quad j = 1, \ldots, n$ 7

$\theta = 1$ indicates a technically efficient DMU while λj is a $N \times 1$ vector showing the proportion of referencing *DMUj* when measuring the efficiency of *DMUq*. The task is to seek the efficiency rating that minimizes cost, θ_q,, subject to two constraints. The first constraint says that the weighted sum of the inputs of the other service units is less than or equal to the inputs of the service unit being evaluated. Second, the weighted sum of the outputs of the other service units is greater than or equal to the service unit being evaluated. The linear programming model above is solved n number of times, once for each DMU, to generate a value of θ for each DMU. Based on data constraint, 86 DMUs (countries) are considered in the DEA framework to capture the efficiency of each top EPI country relative to all possible trading partner. Since, constraints may exist on DMUs that do not allow them to operate at the optimal scale, Varying Returns to Scale (VRS), rather than Constant Return to Scale (CRS) model is adopted. Thus, the restriction $\sum_{1}^{n} \lambda n = 1$ is added as suggested by Banker et al, (1984). This model is less restrictive and allows the best practice level of outputs to inputs to vary with the size of the countries (Halkos and Tzeremes, 2009).

Second Stage Analysis

The second stage utilize the efficiency scores to measure the efficiency level of each top EPI countries in analyzing the effect on trade performance. A number of preliminary analyses were conducted to describe the property of each series and suitability of techniques of estimation. The study first conducts the test for cross-sectional dependence in panels to establish the existence of cross-sectional dependence within the panel variables. Four tests are conducted including Breusch-Pagan LM, Pesaran scaled LM, Bias-corrected scaled, and LM Pesaran CD for reliable decision. The null hypothesis assumes cross-sectional independence against the alternative hypothesis of cross-sectional dependence. Rejection of null hypothesis suggests the existence of cross-sectional dependence among the countries.

In the presence of cross-sectional dependence, traditional panel unit root tests may over-reject the null hypothesis (Bhattacharya et al, 2016). Four traditional tests of unit root are used including Levin, Lin and Chu (Levin et al, 2002), Im, Pesaran and Shin (Im et al, 2003); and the Fishertype tests (ADF-Fisher; PP-Fisher). The cross sectional augmented IPS (CIPS) test is developed by Pesaran (2021) is conducted to account for both heterogeneity and cross-sectional dependence across panels. Further, three panel cointegration tests (Pedroni, 1999 and 2004; Kao, 1999; and Johansen Fisher-Maddala and Wu, 1999) are conducted to examine whether a long-run equilibrium relationship exists among the variables.

Following the establishment of the long-run dynamics, the direction of causality between exports and environmental efficiency in the short-run is determined using the pairwise heterogeneous panel causality test suggested by Dumitrescu and Hurlin (2012). The test considers the dependence among the countries and heterogeneity and can be performed when the time dimension is higher or lower than the cross-section dimension (Koçak and Şarkgüneşi, 2017). which assumes all coefficients to be different across cross-sections and requires variables to be stationary. The VECM Granger causality test of Engle and Granger (1987) is also employed for both panel and individual country analysis.

Long term parameters for the relationship among the variables are estimated using the panel Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) as developed by Pedroni (2000, 2001). The time series FMOLS and DOLS are also adopted for the individual countries. FMOLS is a semi-parametric technique that removes correlation issues and it is asymptotically impartial and accurate while DOLS is particularly robust to the problem of endogeneity and serial correlation by incorporating the leads and lags of the first difference regressors (Kalmaz and Kirikkaleli, 2019).

Due to data constraint, especially on the key variables, 16 of the top 20 EPI countries are selected. As classified by Wendling et al (2020), these countries include Austria, Canada, Denmark, Finland, France, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, and United Kingdom. The description of the data utilized and their sources are presented in Table 2. All data will cover the 1980-2019 period based on data availability.

Table 2: Variable Description and Data Sources

Variable	**Description**	**Measurement**	**Source**
DEA Input Indicators			
ENE	Energy Consumption	Petroleum (Litres)	United States Energy Information Administration
LAB	Labour	Population ages 15-64 (total)	World Bank, World Development Indicators (WDI}
CAP	Capita	Gross fixed capital formation (constant 2010 US$)	World Bank, World Development Indicators (WDI}
DEA Output Indicators			
GDP	Gross Domestic Product	GDP at market prices (constant 2010 US$)	World Bank, World Development Indicators (WDI)
CO2	Carbon Emission	CO2 emissions (kt)	World Bank, World Development Indicators (WDI)
Regression variables			
EXPPC	Export Per Capita	Exports of goods and services per capita (constant 2010 US$)	World Bank, World Development Indicators (WDI)
EXPGDP	Export Intensity	Exports of goods and services (% of GDP)	World Bank, World Development Indicators (WDI)
EFF	Environmental Efficiency	Computed from DEA	-
LAB	Labour	Population ages 15-64, total	World Bank, World Development Indicators (WDI)
GDPPC	GDP per capita	GDP per capita (constant 2010 US$)	World Bank, World Development Indicators (WDI)
PCAP	Physical Capital	Gross fixed capital formation (constant 2010 US$) divided by population	World Bank, World Development Indicators (WDI)
INF	Inflation	Consumer price index (2010 = 100)	World Bank, World Development Indicators (WDI)
EXCH	Exchange rate	Real effective exchange rate index (2010 = 100)	World Bank, World Development Indicators (WDI)

Source: Author Compilation

5.0 Empirical Analysis and Results

5.1 Preliminary Analysis

Table 2 presents the summary statistics of all variables used in the various analysis. Average environmental efficiency among the top EPI countries is 2.9 over the period 1980-2019, ranging from 0.0012 to 58.82. Environmental efficiency is however highest in Indonesia (0.86), ranging from 0.46 to 1.26. The minimum and maximum export intensity (share of export in GDP) is 8.97% and 126.8% respectively, yielding a mean intensity of about 38%. Moreover, export per capita is as high as USD108,504 and as low as USD1,687 among these countries, with an average of about USD16,650. Mean real effective exchange rate is strong at 103 ranging from 69 to 157, while average GDP per capita is considerably high at USD42,256 with minimum of USD17,331 and maximum of USD92,556. The standard deviation shows that environmental efficiency is the least volatile among the variables labour, as captured by the number of people in the working population is the most volatile. The skewness statistics is low and positive for all variables, except the consumer price index (inflation). The summary statistics, therefore suggest that the probability distributions of all variables are normal.

Table 3: Summary Statistics

	EXPGDP	EXPPC	EFF	EXCH	GDPPC	INF	PCAP	LAB
Mean	37.87	16649.62	1.69	102.77	42255.80	80.27	9292.66	18205674
Maximum	126.80	108504.40	58.82	156.98	92556.32	129.00	34174.08	87125283
Minimum	8.97	1686.72	0.0012	69.42	17331.07	2.18	2671.60	142872
Std. Dev.	18.29	13920.30	3.10	14.64	15250.14	23.90	3912.47	21930118
Skewness	1.66	2.09	16.82	1.09	1.12	-0.60	1.33	1.63
Kurtosis	7.19	9.98	295.64	4.65	4.24	2.76	6.34	5.17
Jarque-Bera	762.46*	1769.01*	2313913*	200.25*	174.55*	39.47*	484.85*	408.15*
Observations	640	640	640	640	640	640	640	640

Source: Author Computation

The results of all cross-section dependence tests strongly reject the null hypothesis of no cross-sectional dependence for all variables across the top EPI countries (Table 4). Thus, all of the variables are cross-sectionally correlated and a shock in one country may be transmitted easily to other countries. The test is important due to the regional and macroeconomic linkages from global shocks such as financial and economic crisis, great recession, and oil shocks. Again, most of the top EPI economies are developed with high level of macroeconomic relations such that national policies may have spillover effect on other countries. Consequently, in addition to the traditional panel unit root tests, the cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root test is conducted following Pesaran (2007) to account for the presence of cross-sectional dependence. In particular, the Levin, Lin and Chu (2002); Im, Pesaran and Shin (2003); Augmented Dickey-Fuller (ADF)-Fisher and Phillip-Perron (PP)-Fisher and CIPS unit root tests were conducted for robust decision about the stationarity property of each variable. As reported in Table 5, unit root results indicate that while some variables are stationary at level, others are stationary after first difference. Again, the study used the demeaned series for more robust estimates in the face of cross-sectional dependency, and also analyse the individual country case.

Table 6 presents the panel co-integration test results. For the export per capita equation, all Johnson Fisher, as well as Kao, statistics support the co-integration relationship among the variables. For the export intensity equation, both ADF and PP statistics of the Petroni test, and the Kao and all

Johnson Fisher statistics indicate co-integration relationship among the variables. This suggests a long run relationship irrespective of any short-run shocks.

Table 4: Test of Cross-sectional Dependence

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
INF	5127.331*	301.613*	301.395*	71.571*
EFF	259.158*	6.437*	6.219*	2.612*
EXCH	870.308*	43.493*	43.275*	7.829*
EXPGDP	2420.564*	137.491*	134.273*	44.059*
EXPPC	5022.543*	295.259*	295.042*	70.786*
GDPPC	4990.325*	293.306*	293.088*	70.581*
PCAP	938.044*	47.600*	47.382*	19.930*
LAB	4079.404*	238.073*	237.855*	55.905*

Source: Author Computation

* indicates the rejection of null hypothesis of cross-sectional independence (CD test)

Table 5: Unit Root Test

Variable		INF	EFF	EXCH	EXPGDP	EXPPC	GDPPC	PCAP	LAB
Levin, Lin and Chu	Level	-5.753*	0.042	-3.014*	-0.611	-4.566*	-5.570*	-3.728*	-2.648*
	First Difference	-9.698*	-11.355*	-13.001	-14.825*	-10.705*	-10.394*	-10.652*	-3.485*
Im, Pesaran and Shin	Level	-3.133*	-5.732*	-3.616*	1.298	1.22	-0.028	-0.807	1.523
	First Difference	-9.890*	-19.618*	-13.609*	-14.153*	-12.353*	-10.016*	-10.714*	-5.090*
ADF-Fisher	Level	61.351*	100.446*	63.295*	24.42	22.67	33.279	40.964	26.531
	First Difference	167.134	354.595*	238.763*	250.355*	214.083*	166.599*	178.996*	95.621*
PP-Fisher	Level	387.123*	176.692*	47.466*	19.263	29.83	34.064	17.748	83.836*
	First Difference	239.858*	457.461*	360.454*	361.828*	328.996*	185.129*	195.956*	56.172*
CIPS	Level	-2.749*	-3.205*	-1.992	-2.154***	-1.892	-1.78	-1.886	-2.409*
	First Difference	-3.563*	-5.611*	-5.267*	-4.391*	-4.723*	-4.026*	-4.306*	-2.319**
Decision		1(0)	1(0)	1(0)	1(1)	1(1)	1(1)	1(1)	1(0)

Source: Author Computation

Table 6: Panel Cointegration Results

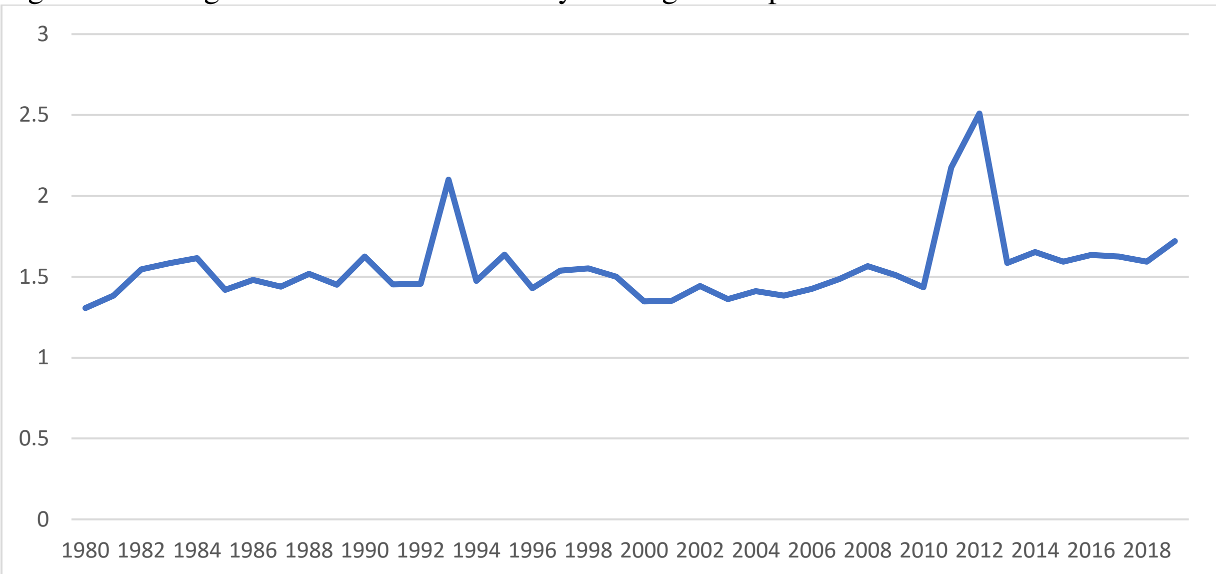
Statistics	Pedroni Test		Kao	Johnson Fisher	
	Within Dimension	Between Dimension		Trace	Max. Eigenvalue
EXPPC = f(EFF, CPI, EXCH, GDPPC, KGDP, LAB)					
v-Statistic	0.211				
rho-Statistic	2.859	3.752			
PP-Statistic	0.656	-0.046			
ADF-Statistic	0.611	-0.612	-4.042*		
R=0				624.4*	330.6*
r≤1				388.0*	165.3*
r≤2				252.6*	96.83*
r≤3				177.1*	77.24*
r≤4				121.8*	65.46*
r≤5				86.19*	62.37*
r≤6				75.71*	75.71*
EXPGDP = f(EFF, CPI, EXCH, GDPPC, KGDP, LAB)					
v-Statistic	-4.593				
rho-Statistic	-0.990	0.563			
PP-Statistic	-11.639*	-16.113*			
ADF-Statistic	-8.588*	-4.071*	-5.328*		
R=0				626.6*	356.7*
r≤1				397.9*	170.7*
r≤2				257.6*	108.1*
r≤3				173.8*	75.04*
r≤4				121.5*	60.14*
r≤5				92.35*	62.50*
r≤6				88.14*	88.14*

Source: Author Computation

5.2 Environmental Efficiency Among the Top-20 EPI Countries

The environmental efficiency scores of each of the selected top EPI countries are reported in Table A in the Appendix. Figure 4 shows improvement in the average environmental efficiency level of these countries over the last four decades, with noticeable spiked in 1993 and 2012. On the average, environmental efficiency stood at 1.31 in 1980, but deteriorated slowly to about 1.35 in the year 2000, after an initial significant improvement to saw these countries reached a peak of 2.1 in 1993. Average environmental efficiency among these countries however was as much as 2.51 in an all-time peak in 2012, before settling at 1.72 in 2019. Thus, a general upward and unstable trend is observed in this efficiency in the last four decades. Many of the top EPI countries are industrialized with high consumption of fossil fuel and were seen as the major contributors to global carbon emissions and other associated gases. In the recent years, these countries are heavily committed to climate change mitigation activities with clear fossil fuel consumption and carbon reduction targets, and are therefore leaders in the campaign again environmental pollution. Whether the observed trends in environmental efficiency in these economies influence export performance or not is empirically investigated in the following sections.

Figure 4: Average Environmental Efficiency Among the Top EPI Countries



Source: Author Computation

5.3 Causal Relationship between Environmental Efficiency and Export

Following the existence of long-run dynamics among the variables, the direction of causality between environmental efficiency and export performance in the short-run is estimated using a pairwise panel and individual country causality test. Results of the pairwise Dumitrescu Hurlin panel causality tests, which assumes that all the coefficients are different across countries, are presented in Table 7. Since all variables are required to be stationary, series are used at their levels of stationarity. Results show evidence of bidirectional causality between environmental efficiency and each of export per capita and export intensity in the short-run. Panel VECM Granger causality analysis, reported in Table 8, however suggests unidirectional causality running from environmental efficiency to each of export per capita and export intensity. The results establish the critical role of environmental efficiency in export performance across the leading countries on the EPI scale, though the need for higher export may present important influence on such efficiency.

Table 8 also presents the country specific VECM Granger causality results. While bidirectional causality exists between environmental efficiency and export per capita only in Sweden, unidirectional causality is found to run from this efficiency to export per capita in Denmark, France, Iceland, Italy, the Netherlands and New Zealand. Export per capita is found to Granger cause environmental efficiency in Austria, Finland, Ireland, Japan, Switzerland and the United Kingdom. For export intensity, Granger causality runs from environmental efficiency to export intensity in Denmark, France, The Netherlands, New Zealand, Norway and Sweden, with bidirectional causality only in Canada. Moreover, export intensity Granger causes environmental efficiency in Austria, Finland, Iceland, Ireland, Japan, Switzerland and United Kingdom. The results therefore provide evidence of strong links between environmental efficiency and export performance these countries, following significant investment in environmental quality. Such investment stems from the huge commitment to reduce environmental pollution, especially carbon emissions, through effective design and implementation of regulations that encourage the adoption of production techniques that are friendly to the environment. Such development reduced negative externality and associated production costs that increases competitiveness. In other countries however, it is the need to remain competitive and increase export market share that engender investment in environmental quality. Therefore, the effect of this efficiency on both export per capita and export intensity is estimated, but the possibility of serial correlation and endogeneity must be accounted for. This is done by adopting the FMOLS and DOLS regression techniques.

Table 7: Pairwise Dumitrescu Hurlin Panel Causality Tests

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
EXPGDP does not homogeneously cause EFF	3.313	2.086	0.0370
EFF does not homogeneously cause EXPGDP	3.067	1.653	0.0984
EXPPC does not homogeneously cause EFF	5.438	5.82818	6.E-09
EFF does not homogeneously cause EXPPC	3.324	2.10550	0.0352

Source: Author Computation

Table 8: VECM Granger Causality tests

	EFF→EXPPC	EXPPC → EFF	EFF→EXPGDP	EXPGDP → EFF
Panel	5.581***	1.960	5.003***	2.611313
Austria	0.816	13.929*	0.814	7.761***
Canada	5.442	2.041	9.232***	15.390*
Denmark	6.224**	0.567	4.524***	2.340
Finland	8.765	21.872*	0.056	12.808**
France	10.105***	7.954	18.548*	2.606
Iceland	9.478**	2.973	1.636	18.472*
Ireland	2.515	14.355*	7.595	17.109*
Italy	6.806**	2.808	3.453	0.866
Japan	0.040	5.360***	0.063080	4.438***
Netherlands	7.455***	0.694	33.392*	2.324
New Zealand	9.276**	0.030	7.917**	0.768
Norway	7.357	2.006	25.483*	5.468
Spain	0.516	0.509	1.595	0.679
Sweden	7.570**	14.122*	20.174*	0.105
Switzerland	3.216742	6.796133***	0.633960	6.323193***
United Kingdom	1.603989	12.13848*	4.200280	6.326543***

Source: Author Computation

5.4 Effect of Environmental Efficiency on Export Performance

Results from both FMOLS and DOLS techniques for export per capita and export intensity are reported in Tables 9 and 10, respectively. Analysis using DOLS yield more improved R-square than that suggested by FMOLS. For instance, R-square statistics is as low as 0.21 (Iceland) in the model estimated by FMOLS, whereas DOLS show that the model explains 77% (New Zealand) of the variation in export per capita, being the least R-square recorded. For the export intensity models, over 70% of the models reported R-square lower than 50% in the FMOLS estimates, and could be as low as 8% (Denmark), whereas the least R-square statistics in the DOLS models is 78% (United Kingdom). This indicates that estimates of DOLS are more reliable both for the export per capita and export intensity models.

Results reported in Table 9 show evidence of significant positive effect of environmental efficiency on export per capita for the panel of 16 top EPI countries. Improvement in this efficiency by 1.0% raised export per capita by 0.01% among these countries, as the capacity to produce cleaner goods increase with greater tendency to meet environmental-related international market standards. This is confirmed at country specific level for Canada, Denmark, France, Italy, Japan, The Netherlands, Norway and The United Kingdom, with elasticity that ranged from 0.02 in each of Japan and Italy to 1.17 in Canada. Surprisingly, coefficients of environmental efficiency in

Ireland (-0.25) and Iceland (-0.10) are negative and statistically significant which may indicate rising costs of compliance with environmental regulation and adoption of clean production technology in the long-run which tends to reduce competitiveness.

Further results show positive and statistically significant coefficient of GDP per capita for the panel analysis. Thus, 1.0% increase in income per capita raised export per capita by about 1.64%, indicating significant role of income and hence, capacity to produce for export and invest in environment-friendly technology on export per capita. The result is valid for 10 of the selected 16 EPI countries, with elasticities ranging from 1.19 (Ireland) to 9.74 (Norway). Results also show that inflation exert significant positive impact on export per capita, while the effect of labour is significant negative, as a continuous rise in the working population may be detrimental to export per capita by increasing pressure on existing production facilities. If fact, 0.13% reduction in export per capita is linked with a 1.0% increase in the number of people in the working population. The positive influence of inflation is consistent across countries such as Austria (0.65), Canada (1.56), France (3.24), Iceland (0.13), Italy (0.33), The Netherlands (1.73), Norway (2.41), Spain (0.59) and The United Kingdom (1.37). The negative influence of labour is also confirmed in Canada (3.97), Finland (-1.73), France (-3.28), Norway (-3.89), Spain (-1.08) and The United Kingdom (-1.74). However, labour had significant increasing role on export per capita in few countries including Italy (3.61), Japan (0.95) and The Netherlands (3.63). The influence of real effective exchange rate and physical capital is found to be negligible in the panel of countries.

Table 9: Long-run Export per Capita Elasticities

	EFF	INF	GDPPC	EXCH	PCAP	LAB	Constant	R-square
Fully Modified Ordinary Least Square								
Panel	0.005(0.003)***	0.010(0.009)	1.389(0.066)*	0.003(0.017)	-0.042(0.014)*	-0.079(0.032)*	-	0.447
Austria	-0.030(0.030)	0.330(0.112)*	2.772(0.239)*	-0.242(0.120)**	-0.016(0.104)	-1.456(0.556)*	22.429(81.86)*	0.592
Canada	-0.208(0.162)	0.312(0.190)	1.462(0.280)*	0.028(0.073)	-0.133(0.133)	-0.702(0.423)***	11.709(5.991)**	0.525
Denmark	-0.027(0.037)	0.068(0.138)	1.005(0.302)*	0.023(0.186)	0.084(0.061)	-0.797(1.269)	11.521(18.483)	0.378
Finland	0.079(0.061)	0.066(0.047)	1.570(0.189)*	0.127(0.119)	-0.260(0.062)*	-0.967(0.470)**	14.123(7.292)***	0.632
France	0.167(0.183)	0.438(0.714)	1.374(2.027)*	-1.955(0.637)	-0.465(0.599)	5.559(3.261)***	-80.598(53.233)	0.955
Iceland	-0.008(0.009)	0.006(0.024)	0.827(0.213)*	-0.179(0.087)**	0.005(0.060)	-0.031(0.132)	1.266(1.628)	0.211
Ireland	0.074(0.032)**	-0.066(0.088)	1.265(0.136)*	-0.119(0.082)	-0.025(0.026)	0.005(0.026)	0.512(2.110)	0.762
Italy	0.017(0.004)*	0.027(0.017)	1.046(0.28)*	-0.346(0.103)*	0.352(0.112)*	2.657(0.756)*	-46.049(13.11)*	0.664
Japan	-0.006(0.006)	0.442(0.132)*	3.380(0.361)*	-0.235(0.061)*	-0.100(0.066)	1.138(0.262)*	-21.371(4.565)*	0.633
Netherlands	0.042(0.117)	2.018(0.127)*	0.818(0.483)***	-0.331(0.259)	0.410(0.153)*	1.448(0.596)**	-22.221(8.782)*	0.995
New Zealand	0.035(0.039)	0.014(0.040)	0.709(0.131)*	-0.037(0.030)	-0.083(0.046)***	-0.079(0.064)	1.366(0.748)***	0.422
Norway	-0.003(0.076)	0.959(0.282)*	0.171(1.459)	-0.533(0.493)	-0.730(0.250)*	-1.193(0.744)	28.639(9.838)*	0.917
Spain	-0.117(0.077)	0.069(0.068)	0.532(0.361)	0.034(0.096)	-0.208(0.098)**	-0.605(0.270)**	11.204(4.337)*	0.316
Sweden	0.583(0.342)***	0.435(0.256)***	3.295(1.167)*	-0.342(0.501)*	0.401(0.432)	4.967(1.905)*	-72.398(30.350)**	0.962
Switzerland	-0.002(0.013)	-0.081(0.083)	2.423(0.305)*	-0.001(0.111)	-0.250(0.101)*	-0.091(0.139)	2.587(1.809)	0.505
UK	0.073(0.044)***	0.0053(0.037)	1.018(0.246)*	-0.051(0.053)	-0.015(0.059)	-0.553(0.199)*	9.386(3.397)*	0.397
Dynamic Ordinary Least Square								
Panel	0.010(0.004)*	0.054(0.019)*	1.640(0.165)*	0.021(0.025)	-0.009(0.245)	-0.126(0.053)*	-	0.819
Austria	0.134(0.096)	0.646(0.341)*	4.425(0.855)*	-0.450(0.254)***	0.261(0.176)	-2.744(1.605)	40.272(22.529)***	0.937
Canada	1.168(0.261)*	1.556(0.266)*	2.532(0.596)*	-0.051(0.082)	0.537(0.265)***	-3.972(0.732)*	53.626(9.988)*	0.930
Denmark	0.186(0.079)**	-0.194(0.289)	2.554(2.346)	0.412(0.422)	0.209(0.089)**	0.163(2.232)	-4.958(32.235)	0.840
Finland	0.059(0.079)	0.040(0.113)	1.451(0.615)**	0.007(0.155)	-0.339(0.066)*	-1.731(0.676)**	26.652(10.286)**	0.968
France	0.208(0.054)*	3.240(0.186)*	-1.949(1.179)	-0.815(0.088)*	-0.216(0.130)	-3.282(0.803)*	55.311(13.066)*	0.999
Iceland	-0.101(0.016)*	0.134(0.055)**	0.297(0.416)	-0.208(0.161)	-0.042(0.060)	-0.115(0.227)	2.554(3.228)	0.906
Ireland	-0.247(0.110)**	-0.347(0.339)	1.192(0.612)***	0.042(0.183)	-0.143(0.124)	0.834(0.692)	-9.392(8.435)	0.947
Italy	0.015(0.007)***	0.331(0.104)*	5.699(1.597)*	-0.470(0.235)***	0.597(0.198)*	3.611(1.452)**	-64.275(25.083)**	0.923
Japan	0.021(0.010)***	0.397(0.248)	5.389(1.272)*	-0.231(0.150)	0.187(0.309)	0.951(0.447)**	-18.876(7.925)**	0.951
Netherlands	0.114(0.054)**	1.733(0.147)*	2.359(0.497)*	-0.239(0.133)***	-0.186(0.283)	3.629(0.895)*	-55.296(13.187)*	0.999
New Zealand	0.170(0.149)	-0.009(0.129)	2.898(0.806)*	0.061(0.103)	-0.101(0.212)	0.137(0.144)	-2.880(1.650)***	0.768
Norway	0.184(0.079)**	2.410(0.384)*	9.735(2.051)*	-0.734(0.558)	-0.421(0.142)*	-3.891(1.008)*	60.823(14.941)*	0.995
Spain	0.109(0.079)	0.585(0.075)*	3.215(0.723)*	-0.094(0.065)	-0.071(0.097)	-1.080(0.235)*	15.738(3.937)*	0.932
Sweden	0.917(1.283)	0.352(1.840)	7.699(8.315)	-0.441(3.636)	0.607(2.145)	5.471(13.197)	-81.908(205.481)	0.985
Switzerland	-0.033(0.048)	-0.197(0.260)	-0.703(2.418)	-0.576(0.565)	0.545(0.405)	0.509(0.505)	-5.811(6.116)	0.849
UK	0.197(0.057)*	1.370(0.083)*	1.331(0.844)	-0.315(0.131)	-0.262(0.086)*	-1.736(0.508)*	34.429(8.765)*	0.999

Source: Author Computation

Robustness results using the export intensity models are presented in Table 10. Estimates show that the effect of environmental efficiency on export intensity is similar to those obtained for export per capita. In particular, this efficiency exerted significant positive effect on export intensity with an elasticity of about 0.01 using the panel of countries. Similar findings are evident at individual country level for Canada (0.77), Denmark (0.23), France (0.22), Japan (0.03), Spain (0.29) and The United Kingdom (0.37). This implies that higher stringent environmental regulation enhances environmental commitment and efficiency of the top EPI countries which in turn raise their capacity to produce for export, hence the share of output being exported. Again, in Iceland, the effect of environmental efficiency on export intensity is negative, as 1.0% increase in this efficiency reduced the intensity of export by about 0.08%. For other countries, the contribution of environmental efficiency to export intensity is negligible.

Table 10: Long-run Export Intensity Elasticities

	EFF	INF	GDPPC	EXCH	PCAP	LAB		R-square
Fully Modified Ordinary Least Square								
Panel	0.001(0.004)	-0.00003(0.011)	0.368(0.083)*	-0.029(0.021)	-0.078(0.018)*	0.004(0.040)	-	0.086
Austria	-0.023(0.036)	0.509(0.137)*	2.453(0.292)*	-0.297(0.147)**	-0.065(0.128)	-2.236(0.681)*	34.111(10.019)*	0.473
Canada	-0.456(0.181)*	0.251(0.212)	1.108(0.311)*	0.146(0.081)***	-0.408(0.148)*	-0.389(0.148)	8.148(6.673)	0.431
Denmark	-0.047(0.052)	0.069(0.197)	0.468(0.430)	-0.086(0.264)	0.002(0.086)	-0.264(1.805)	4.300(26.289)	0.083
Finland	0.148(0.091)	0.110(0.069)	0.735(0.282)*	0.222(0.178)	-0.338(0.093)*	-1.272(0.701)***	17.976(10.879)***	0.360
France	0.150(0.084)***	-0.495(0.329)	0.883(0.933)	-1.779(0.293)*	-0.389(0.276)	3.387(1.502)**	-45.170(24.513)***	0.894
Iceland	-0.008(0.011)	0.031(0.027)	-1.091(0.246)*	-0.506(0.100)*	0.269(0.069)*	-0.198(0.152)	3.977(1.884)**	0.401
Ireland	0.098(0.040)*	-0.202(0.108)***	0.437(0.168)*	0.001(0.102)	-0.059(0.033)***	0.310(0.203)	-3.986(2.608)	0.191
Italy	0.022(0.006)*	0.056(0.028)**	-0.241(0.446)	-0.761(0.164)*	0.642(0.178)*	4.480(1.206)*	-76.999(20.91)*	0.479
Japan	-0.003(0.007)	0.890(0.174)*	3.648(0.473)*	-0.411(0.080)*	-0.128(0.087)	1.577(0.343)*	-30.579(5.981)*	0.634
Netherlands	0.035(0.061)	1.269(0.067)*	0.972(0.253)*	-0.741(0.136)*	-0.111(0.080)	-3.412(0.312)*	57.332(4.600)*	0.969
New Zealand	0.183(0.099)***	0.063(0.099)	-0.310(0.329)	-0.183(0.075)**	-0.023(0.115)	0.093(0.161)	-1.663(1.881)	0.165
Norway	-0.008(0.057)	-0.591(0.211)*	0.399(1.088)	0.098(0.368)	-0.705(0.187)*	1.633(0.555)*	-16.285(7.337)**	0.407
Spain	-0.125(0.117)	0.016(0.104)	-0.601(0.550)	-0.092(0.145)	-0.229(0.150)	-0.278(0.411)	6.497(6.606)	0.155
Sweden	0.488(0.229)**	-0.099(0.171)	2.010(0.790)*	-0.456(0.335)	0.009(0.289)	1.326(1.173)	-17.051(20.280)	0.861
Switzerland	-0.002(0.013)	0.069(0.086)	1.842(0.315)*	-0.134(0.115)	-0.205(0.105)**	-0.071(0.144)	2.065(1.871)	0.412
UK	0.106(0.062)***	-0.001(0.052)	-0.337(0.345)	-0.041(0.074)	-0.089(0.083)	-0.332(0.278)	5.765(4.757)	0.127
Dynamic Ordinary Least Square								
Panel	0.013(0.005)*	0.115(0.025)*	0.759(0.211)*	0.0003(0.033)	-0.002(0.033)	-0.218(0.072)*	-	0.797
Austria	0.161(0.111)	0.856(0.393)**	4.471(0.986)*	-0.597(0.293)***	0.212(0.203)	-3.635(1.850)***	53.842(25.971)***	0.927
Canada	0.769(0.269)*	1.412(0.274)*	0.947(0.614)	0.124(0.085)	0.152(0.273)	-3.282(0.755)*	44.746(10.30)*	0.927
Denmark	0.228(0.118)***	0.030(0.429)	5.554(3.492)	0.942(0.627)	0.270(0.133)***	-1.137(3.322)	10.769(47.978)	0.832
Finland	0.087(0.180)	0.417(0.259)	0.689(1.408)	0.124(0.356)	-0.293(0.152)***	-3.669(1.547)**	53.276(23.556)**	0.921
France	0.222(0.032)*	1.229(0.110)*	0.394(0.697)	-1.024(0.052)*	-0.472(0.077)*	-1.837(0.475)*	34.88(7.725)*	0.998
Iceland	-0.078(0.015)*	0.067(0.053)	-1.088(0.403)**	-0.472(0.157)*	-0.092(0.058)	-0.092(0.220)	3.760(3.129)	0.969
Ireland	-0.139(0.173)	-0.188(0.535)	0.278(0.965)	0.022(0.289)	-0.020(0.196)	0.440(1.092)	-5.068(13.306)	0.831
Italy	0.012(0.009)	0.460(0.130)*	6.010(1.983)*	-0.805(0.292)*	0.770(0.246)*	0.592(1.803)*	-98.452(1.803)*	0.920
Japan	0.026(0.02)***	0.488(0.347)	3.927(1.785)**	-0.181(0.211)	0.015(0.434)	0.853(0.627)	-17.187(11.119)	0.951
Netherlands	0.058(0.050)	1.290(0.136)*	2.964(0.461)*	-0.409(0.123)*	-0.344(0.262)	-3.875(0.831)*	63.790(12.233)*	0.996
New Zealand	-0.054(0.208)	-0.262(0.181)	4.962(1.129)*	0.116(0.145)	-0.850(0.297)*	0.618(0.202)*	-5.782(2.311)**	0.841
Norway	-0.043(0.107)	-0.110(0.517)	7.399(2.761)*	0.733(0.751)	-0.039(0.192)	1.579(1.357)	-22.670(20.114)	0.885
Spain	0.287(0.115)**	0.646(0.108)*	2.962(1.050)*	-0.318(0.095)*	-0.097(0.141)	-0.538(0.342)	6.504(5.713)	0.925
Sweden	1.117(0.753)	0.147(1.080)	1.229(4.880)	-1.202(2.134)	0.259(1.259)	-1.104(7.744)	19.076(120.582)	0.964
Switzerland	0.009(0.043)	0.031(0.231)	-3.651(2.148)	-1.209(0.502)**	0.631(0.360)***	0.749(0.448)	-8.122(5.435)	0.895
UK	0.370(0.126)*	0.410(0.182)*	1.253(1.855)	0.548(0.289)***	-0.346(0.190)***	-2.250(1.117)***	34.064(19.263)***	0.780

Source: Author Computation

Moreover, results reveal a significant positive impact of GDP per capita on export intensity with elasticity of 0.76 for the panel model, while the influence of real effective exchange rate is insignificant. As expected, higher income per capita in these economies enhances investment in clean innovation and technology to improve their environmental performance and increases their productive capacity for export. These finding is confirmed in individual countries such as Austria, Italy, Japan, The Netherlands, New Zealand, Norway and Spain. Since most of these countries have stable exchange rate, its small changes may not cause noticeable changes in export intensity. Like export per capita, the impact of inflation (labour) on environmental efficiency is significant positive (negative) in the panel estimates. Thus, 1.0% increase in inflation rate raises export intensity by 0.12%, but a similar increase in the size of working population (labour) reduced this the share of export in GDP by 0.22%. While the rising export intensity in the face of rising inflation may be surprising given the associated higher production costs, it may indicate that export share of GDP responds in line with higher values of output. This result is evident Austria, Canada, France, Italy, The Netherlands, Spain and The United Kingdom. The negative effect of labour is observed in Austria, Canada, Finland, France, The Netherlands and The United Kingdom. This indicates the reducing effect of labour on export intensity, as the working population keeps expanding given the existing level of capital. The effect of physical capital per capita on export intensity is insignificant for the panel of selected countries.

5.5 Discussions

The study provides evidence of higher average environmental efficiency among the top countries on the EPI in the last decade than the preceding decades. This efficiency performance is a reflection of the huge commitment of the top EPI countries to drastically reduce fossil fuel consumption and meet (or surpass) their carbon reduction targets. This follows rounds of global meetings and consensus, in the last few decades. These commitments are still very evident in the various recent declarations and effort across the top EPI countries. For instance, many of these economies have banned or restricted public investment in fossil fuels, including natural gas. Some of them, especially those in Europe including France, Germany, and the United Kingdom, recently announced a halt in public funding for certain fossil fuel projects abroad. Norway's sovereign wealth fund, the largest in the world, sold out its investment in major mining and energy companies, especially coal, following environmental concerns. In 2018, following the passage of a bill, Ireland became the first country to pledge to entirely divest from fossil fuels, with plans to sell off investments in coal, oil, gas and peat. Major fossil fuel divestment campaign is being staged in Finland, while Denmark became the first major oil-producing nation to announce an end to state-approved oil exploration.

Causality results indicate strong environmental efficiency-export performance nexus among these countries. Thus, the huge investment in environmental quality may promote healthy production environment and enhance the quality of products in terms of meeting the level of environmental, as well as Sanitary and Phytosanitary, standards in international markets, hence enhancing acceptability. Thus, the need to remain competitive while increase the share of export market may be an important consideration in the trade-environmental efficiency links for these countries.

Estimates show that environmental efficiency among the top EPI countries is an important driver of export per capita, as evident in the panel of countries, as well as in Canada, Denmark, France, Italy, Japan, The Netherlands, Norway and The United Kingdom. Thus, the higher competitiveness of most of these countries in the global market may be linked with their capacity to produce cleaner goods which are able to meet environment-related international market standards. This finding is consistent with Doganay et al (2014) where environmental efficiency is found to promote bilateral export in a panel of 111 countries, and Mulatu et al (2004) who found significant influence of environmental stringency differential on trade in dirty manufactured commodities in Germany, USA and the Netherlands. The findings also partly corroborate Xu (2000) who found no evidence of reducing effect of more stringent environmental regulation on total exports, exports of ESGs and exports of non-resource-based ESGs among 20 countries. In the few countries, such as Ireland and Iceland, where negative influence of environmental efficiency on export per capita is found, high cost of environmental regulation compliance may limit export performance in the long-run. Estimates using export intensity are largely consistent with those obtained using export per capita.

6.0 Conclusion and Implications for Policy

The environmental implication of production processes continues to draw policy attention around the world. The quest for sustainability and greener economies has intensified the call for more stringent environmental regulation, hence environmental efficiency of production processes that produce growth. Since trade activities represent a huge part of economic growth, while countries are becoming increasingly cautious of their imports, environmental efficiency becomes an integral consideration for trade. A number of countries have made considerable progress overtime in terms of environmental sustainability, with improved export performance over the last four decades. The study investigates the link between environmental efficiency and export performance among the top 20 countries on the environmental performance scale, using data covering the period 1980-2019.

The study employed the classic comparative advantage theory of international trade which emphasizes the relative costs of production as the main driver of specialization and export. The analysis is conducted in two stages. The first stage computed the environmental efficiency scores using the slack-based data envelopment analysis with the varying returns to scale assumption. In the second stage analysis, the efficiency scores generated are used are the key determinant variable.

The study adopted the heterogenous panel and VECM Granger causality approaches to establish the nature of causality between environmental efficiency and export performance. Further, the FMOLS and DOLS estimation techniques were employed to analyze the effect of environmental efficiency on export performance.

Estimates from the pairwise Dumitrescu Hurlin panel causality tests reveal bidirectional links between export per capita (and export intensity) and environmental efficiency. This shows that the huge investments of the top EPI countries on environmental quality and climate change mitigating activities have important influence on their export performance. This, in turn, contributes to improvement in environmental efficiency through higher foreign proceeds and the need to remain competitive. The VECM analysis confirms this finding in Canada and Sweden, with significant unidirectional causal links running from either export to environmental efficiency or otherwise observed across most of the countries. Further, significant positive effect of environmental efficiency on export per capita and export intensity is found among the top EPI countries. In these countries, the capacity to produce cleaner goods for export appear to increase with the greater investment in environmental efficiency and the need to meet environment-related international market standards. Important implications for policy are therefore derived.

The study provides strong evidence for the role of environmental efficiency in countries' efforts to improve their global competitiveness in trade-related activities. This follows the increased awareness for the global health and environmental implication of production and consumption activities with increasing interdependency among countries. Thus, the study emphasizes increased global investment in environmental efficiency as the global economies grow. Further research is still required to provide developing countries case studies on the environmental efficiency-trade links, especially at bilateral trade level, which may reveal differences across markets. Product level analysis can also be considered as environment-related data becomes available for these economies. This is pertinent as investment in environment and sustainability related efforts are still largely low in these economies while their competitiveness in global trade remains marginal and primary product driven.

Availability of data and materials

The data utilized for this study are publicly available as stated under data sources. All data used are however available on request.

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Declarations

Competing interests

This study has no conflicting financial interests.

Authors' contributions

Not Applicable

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Appendix

Table A: Environmental Efficiency Scores

Year	Japan	Canada	UK	France	Italy	New Zealand	Norway	Sweden	Switzerland	Denmark	Austria	Finland	Netherlands	Spain	Iceland	Ireland
1980	1.70	1.00	1.00	1.38	1.71	1.45	1.00	1.66	1.94	1.38	1.20	0.84	1.20	1.63	1.12	0.68
1981	1.63	1.00	1.07	1.48	1.78	1.45	1.55	1.60	2.59	1.56	1.10	0.91	1.35	1.69	0.69	0.68
1982	1.99	0.98	1.12	1.45	1.75	2.28	1.00	1.72	2.60	1.53	1.26	1.11	1.57	1.77	1.62	0.97
1983	1.00	0.97	1.13	1.52	1.79	2.22	1.95	1.69	2.82	1.58	1.47	1.06	1.49	1.83	1.80	1.03
1984	1.00	0.99	1.35	1.63	1.82	2.20	1.67	1.68	3.26	1.58	1.44	1.14	1.41	1.94	1.63	1.10
1985	1.00	1.04	1.10	1.64	1.81	1.90	1.70	1.54	1.00	1.34	1.35	0.96	1.41	2.10	1.68	1.13
1986	1.00	1.07	1.08	1.46	1.57	1.85	1.46	1.62	2.47	1.30	1.38	0.99	1.46	2.10	1.65	1.24
1987	1.00	1.02	1.05	1.51	1.54	1.81	1.39	1.70	2.61	1.27	1.40	0.94	1.47	2.03	1.72	0.57
1988	1.00	1.00	1.10	1.60	1.59	1.81	1.40	1.55	2.65	1.40	1.53	0.96	1.53	2.05	2.13	0.96
1989	1.00	0.96	1.09	1.52	1.56	1.83	1.19	1.43	2.39	1.56	1.51	0.93	1.42	1.59	2.17	1.07
1990	1.52	0.98	1.62	1.50	1.43	1.85	3.47	1.46	2.77	1.40	1.25	0.86	1.37	1.54	2.01	0.98
1991	1.55	0.97	1.15	1.54	1.45	1.94	1.48	1.53	2.43	1.13	1.12	0.95	1.26	1.54	2.08	1.13
1992	1.52	0.98	1.13	1.57	1.41	1.85	1.47	1.72	2.79	1.22	0.79	1.24	1.25	1.45	1.73	1.17
1993	1.00	1.04	1.19	1.61	1.56	1.71	1.63	2.57	11.63	1.28	1.12	1.29	1.31	1.74	1.60	1.32
1994	1.00	1.01	1.18	1.68	1.56	1.63	1.23	2.03	2.92	1.21	1.15	1.19	1.34	1.67	1.54	1.25
1995	1.53	1.00	1.21	1.72	1.53	1.78	1.22	1.99	4.95	1.21	1.11	1.12	1.33	1.68	1.61	1.22
1996	1.00	1.07	1.20	1.67	1.53	1.54	1.00	2.10	2.67	1.15	1.07	1.02	1.29	1.76	1.65	1.16
1997	1.52	1.04	1.27	1.82	1.49	1.53	2.06	2.32	2.57	1.19	1.10	0.99	1.36	1.53	1.67	1.15
1998	1.51	1.05	1.19	1.68	1.41	1.70	2.01	2.43	2.65	1.22	1.17	1.10	1.45	1.50	1.57	1.20
1999	1.47	1.01	1.18	1.61	1.33	1.45	1.86	2.35	2.71	1.27	1.08	1.07	1.42	1.39	1.55	1.23
2000	0.00	1.03	1.14	1.57	1.26	1.50	1.08	2.17	2.86	1.33	1.10	1.13	1.47	1.24	1.42	1.25
2001	1.43	1.03	1.09	1.52	1.20	1.37	1.00	2.02	2.55	1.22	1.07	1.01	1.40	1.24	1.40	1.08
2002	1.38	1.11	1.09	1.73	1.15	1.38	2.03	1.93	2.65	1.17	1.06	1.03	1.48	1.17	1.75	0.98
2003	1.39	0.99	1.10	1.52	1.09	1.27	1.70	1.94	2.67	1.04	1.01	0.90	1.52	1.11	1.51	1.04
2004	1.35	1.00	1.19	1.29	1.11	1.33	1.79	2.05	2.72	1.18	1.10	0.96	1.56	1.14	1.71	1.11
2005	1.00	1.00	1.15	1.34	1.03	1.32	1.83	2.14	2.63	1.24	1.17	1.22	1.73	1.08	1.13	1.12
2006	1.35	0.98	1.19	1.93	1.09	1.42	1.82	2.33	2.69	1.04	1.36	1.09	1.63	1.10	0.51	1.26
2007	1.31	1.02	1.16	2.17	1.05	1.47	1.00	2.19	2.98	1.31	1.43	1.20	1.54	1.10	1.57	1.29
2008	1.34	0.96	1.27	1.39	0.00	1.56	1.55	2.39	2.94	1.43	1.46	1.35	1.56	1.24	3.06	1.55
2009	1.21	1.12	1.27	1.45	0.00	1.60	1.27	2.20	2.25	1.45	1.40	1.20	1.49	1.34	3.38	1.50
2010	1.27	1.02	1.29	1.00	1.22	1.57	1.00	2.17	1.32	1.47	1.42	1.11	1.50	1.59	2.36	1.65
2011	1.00	1.02	1.38	1.81	1.22	1.53	1.97	2.02	2.92	1.65	1.37	1.19	1.55	1.63	2.18	1.71
2012	1.42	0.99	1.24	1.75	1.23	1.36	1.81	2.19	1.00	1.49	1.42	1.32	1.58	1.71	2.51	1.44
2013	1.00	1.01	1.28	2.13	1.33	1.39	1.58	2.07	2.54	1.54	1.34	1.30	1.45	1.65	2.30	1.48
2014	1.00	0.98	1.44	1.75	1.60	1.39	1.57	2.08	2.82	1.75	1.41	1.29	1.45	1.71	2.73	1.46
2015	1.16	0.96	1.50	1.62	1.40	1.23	1.57	2.22	2.71	1.75	1.30	1.45	1.37	1.75	2.43	1.09
2016	1.15	0.96	1.65	1.57	1.41	1.35	1.53	2.19	2.48	1.83	1.38	1.38	1.47	1.89	2.56	1.37
2017	1.11	1.00	1.58	1.76	1.45	1.30	1.53	2.13	2.58	1.81	1.36	1.36	1.43	1.78	2.60	1.22
2018	1.03	0.99	1.64	1.70	1.45	1.32	1.63	1.91	2.60	1.71	1.33	1.31	1.45	1.72	2.66	1.04
2019	1.11	1.03	1.56	2.55	1.44	1.33	1.42	2.31	2.54	1.97	1.44	1.31	1.42	1.78	2.76	1.54