The Effect of Energy Consumption and Economic Growth on Environmental Sustainability in Egypt: Financial Development and Globalization, Do They Have a Role?

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Abstract

The realization of environmental sustainability and the mitigation of the impact of climate change has become a global objective. The present paper tackles the effect of energy consumption, economic growth, financial development and globalization on the scale, intensity, and damage effects of carbon dioxide emissions in Egypt during the period 1990 – 2020. In addition, causality directions in the short run and the long run are investigated and the dynamic behavior of environmental sustainability is described.

In order to achieve its objective, the present study relied on the co-integration analysis using the Autoregressive Distributed Lag (ARDL) technique, Sasabuchi-Lind-Mehlum test, and Granger causality test within the framework of the Vector Error Correction Model (VECM) and Toda-Yamamoto causality analysis; in addition to impulse response functions and the analysis of variance components.

The results of the co-integration test revealed a long run correlation between carbon dioxide emissions and the

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explanatory factors. The study findings also showed that economic growth, energy consumption, globalization, and financial development reduce environmental sustainability. Moreover, the validity of the environmental Kuznets curve (EKC) hypo thesis was confirmed when applied to the Egyptian economy. Hence the income level effect on the emissions scale becomes negative when the annual real income per capita exceeds the amount of 33841.5 Egyptian Pounds.

According to the study results, causality directions proved to be weak and sensitive to the causality test applied in this study. A mutual causality relationship was revealed between the level of globalization and the scale and the damage of carbon dioxide emissions. A one-way relationship ran from the income level to the scale and the intensity of emissions; and a one-way relationship flowed from the scale of emissions to financial development.

Keywords: Carbon dioxide emissions, economic growth, energy consumption, environmental sustainability, Financial development, globalization.

أثر استهلاك الطاقة والنمو الاقتصادي على الاستدامة البيئية في مصر: هل للتنمية المالية ومستوي العولمة دور؟

ملخص

لقد أصبح تحقيق الاستدامة البيئية مع تقليل تأثير تغير المناخ مسعى عالميًا. ومن ثم تناولت هذه الدراسة تأثير استهلاك الطاقة والنمو الاقتصادي والتنمية المالية والعولمة على حجم وكثافة واضرار انبعاثات ثاني أكسيد الكربون في مصر خلال الفترة (1990–2020)، مع بحث اتجاهات السببية في الأجلين القصير والطويل، مع وصف السلوك الحركي للاستدامة البيئية. وفي سبيل تحقيق ذلك اعتمدت الدراسة علي التكامل المشترك باستخدام تقنية الانحدار الذاتي لفترات الإبطاء الموزعة (ARDL) ، هذا بالإضافة إلي اختبار (Sasabuchi–Lind–Mehlum)، واختبار Granger للسببية في إطار (VECM)، وسببية Toda-Yamamoto، وأخيراً دوال الاستجابة للصدمات وتحليل مكونات التباين. وقد كشفت نتائج اختبار التكامل المشترك عن ارتباط طويل المدى بين انبعاثات ثاني أكسيد الكربون والعوامل المفسرة، مما يشير إلى دليل على التكامل المشترك. كما أظهرت النتائج أن النمو الاقتصادي واستهلاك الطاقة، والعولمة، والتنمية المالية يقللون من الاستدامة البيئية. كما أثبتت الدراسة صحة فرضية منحنى كوزنتس البيئي (EKC) للاقتصاد المصري. فمستوى الدخل يتحول تأثيره إلى سلبي على حجم الانبعاثات عندما يتجاوز متوسط دخل الافراد الحقيقي حاجز 33841.5 جنيه. كما أظهرت النتائج أن اتجاهات السببية غير قوية وحساسة تجاه تقنية اختبار السببية المستخدم. فنجد علاقة سببية ثنائية الاتجاه بين مستوي العولمة وبين حجم وأضرار الانبعاثات. بينما هناك علاقة سببية أحادية الاتجاه من مستوي الدخل إلى حجم وكثافة الانبعاثات، بالإضافة إلى وجود علاقة سببية أحادية الاتجاه من حجم الانبعاثات إلى التنمية المالية.

الكلمات المفتاحية: انبعاثات ثاني أكسيد الكربون، النموالاقتصادي، استهلاك الطاقة،الاستدامة البيئية، التنمية المالية، العولمة.

1. Introduction

The great economic expansion and industrialization substantially increased energy consumption and environmental degradation, thus raising serious challenges for sustainable development (Shan, et al.,2021). In year 2019, global energy consumption rose by as much as 103% (BP. British Petroleum., 2021). On one hand, energy consumption is a basic requirement for economic growth; on the other hand, it is the main cause of environmental degradation. Climate change is closely related to energy consumption and greenhouse gases (GHGs) (Awosusi, 2021) . Numerous environmental studies stressed the need to mitigate gases and in particular, carbon dioxide emissions which represent the major part of greenhouse gases(Orhan, ,et al.2021) . Therefore, understanding the reasons behind the increase of carbon dioxide emissions and devising adequate GHG mitigating schemes have become a vital concern for all governments and for Egypt in particular since Egypt relies heavily on fossil fuel energy. It is well-known that fossil energy consumption has a detrimental effect on the quality of environment (Kihombo, et al.,2021) . Although the sources of renewable energy represent an important part of the energy mix in Egypt, they are still largely unexploited. In addition, energy consumption in Egypt is increasing due to population growth, rapid urban expansion, and economic expansion, thus representing an essential threat to environmental sustainability. During the study period (1990 – 2020), the consumption of fossil fuel energy amounted to 95.87% approximately of total energy consumption (www.worldbank.org).

The present paper investigates the relationships between energy consumption (EC), economic growth (GDP), financial development (FD), and globalization (GLO) on one hand and carbon dioxide emissions CO_2 on the other hand in Egypt.

In recent years, numerous researchers focused on the possible influence of globalization on sustainability. (Dreher, 2006) An index of globalization was formulated including economic, social and political variables , and using additional subsidiary indexes for a better understanding of that relationship (Gygli,et al.,2019). Although previous studies did prove the existence of a correlation between GLO and CO_2, their findings were not conclusive. For example, studies concerning the biggest energy consuming countries(Rahman, 2020) , a study covering 23 African countries (Villanthenkodath, et al.,2021), and yet another study (He, X.et al. 2021) revealed a negative relationship between GLO and CO_2; whereas studies on the BRICS countries (Pata, 2021), the WAME countries (Kihombo, 2021) , and another study (Kirikkaleli, et al.,2021) found a positive relationship between GLO and CO_2.

Moreover, financial development may have an important impact on environmental degradation in various ways. For example, loans advanced by financial institutions may be used for establishing new projects that will consume more energy, exploit new lands and generate additional waste. Furthermore, individuals obtaining loans acquire more purchasing power and increase their consumption of resources, consequently increasing environmental degradation. However, financial institutions may encourage technological progress that reduces energy consumption and environment degradation (Tufail, et al.,2021). Moreover, financial institutions can play a positive role through financing research and development initiatives that may yield technological innovations. Hence, previous literature generated contradictory results concerning the relationship between FD and CO2. For example, two studies, (Baloch,et al.,2021) and (Oluwajana, et al.2021) , found a negative correlation while other studies, (Xu, Z.,et al.2018) and (Salahuddin, et al.,2018), revealed a positive correlation between these two variables.

From these studies, we deduce that globalization, energy consumption, economic expansion and financial development have varying effects on environment degradation. Currently, Egypt is facing increasing globalization operations and growing energy consumption that stand as a serious threat to the quality of environment. Therefore, the present study aims at helping policy makers in their endeavor to adopt more effective schemes for reducing environment degradation around the World in general, and particularly in Egypt. Moreover, this study offers essential contributions to the existing literature through investigating the influence of energy consumption, economic growth, financial development, and globalization on carbon dioxide emissions in Egypt while including in the analysis the basic factors of economic prosperity which have been disregarded by previous studies.

This paper is divided into five sections. Following the Introduction, Section 2 reviews previous relevant studies; Section 3 describes the specifications of the research models; Section 4 discusses the study findings; and Section 5 offers deductions and recommendations for future studies.

2. Literature Review

This section presents a detailed discussion of previous research studies investigating the relationship between energy consumption, economic growth, financial development, and globalization, on one hand, and carbon dioxide emissions on the other hand.

2.1. Energy Consumption, Economic Growth, and CO2 Emissions

According to empirical studies, it is generally accepted that a relationship exists between energy consumption, gross domestic product and carbon dioxide emissions. Energy is necessary for production leading to economic expansion, but also to environment degradation. A study (Chebbi, 2010) carried out in Tunisia, using the co-integration methodology and covering the period 1971 – 2005, found a positive relationship between energy consumption and carbon dioxide emissions. Similarly, a study (Salahuddin, & Gow, 2014) concerning the economies of the Arab Gulf Council member countries assessed the relationship between energy consumption, gross domestic product and carbon dioxide emissions during the period 1980 – 2012, through using the Pooled Mean Group estimator (PMG) and a causality test. Results revealed an insignificant relationship between GDP and CO2; and a positive relationship between energy consumption and CO2. In addition, a feedback causality correlation was observed between EC and CO2. Another research (Nain, et al.,2017) exploring the relationship between these three variables (EC- GDP - CO2) in India, applied the Toda-Yamamoto causality test to a collection of data featuring the period 1971 – 2011. The study results revealed a mutual causality relationship between EC and CO2. Another study (Wang, et al.,2016) covering 170 economies and using data over the period 1980 – 2011 and applying the VECM discovered that both EC and GDP generated CO2. Moreover, a mutual causality relationship existed between EC and CO2, while a one-way relationship was found going from GDP to CO2. A study (Salari, et al.,2021) carried out in the United States of America and using the ordinary least squares (OLS) methodology and panel data for the period 1997 – 2016, concluded that both EC and GDP had a positive effect on CO2. That same study also proved the validity of the Environmental Kuznets curve (EKC) through using the ARDL model and a causality test.

The relationship between EC- GDP – CO2 was furthermore investigated in Pakistan over the period 1972 – 2018(Abbasi, et al.,2021) . The study results indicated that both EC and GDP contributed to environment degradation. According to Granger causality test, GDP had a positive effect on CO2. Another study (Xu, et al.,2018) also proved the validity of a positive correlation between EC – GDP - CO2. In order to estimate the relationship between EC - GDP - CO2 in Brazil during the period 1990 -2018, the researchers (Su, et al.,2021) used the Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) methodologies as well as causality tests to prove that any increase in EC and GDP contributed to environment degradation.

A study (Acheampong, et al.,2019) showed that the increasing GDP led to higher levels of CO2 emissions. Another study (Ayobamiji, & Kalmaz, 2020) using collected data for the period 1980 – 2017 in Nigeria revealed that environment degradation had resulted from a surge in EC and economic growth.

2.2. Financial development and Carbon Dioxide Emissions

The correlation between FD and CO2 was investigated by a study (Shoaib,et al.2020) covering a group of developing countries G8 and a group of developed countries D8 and using panel data for the period 1999 – 2013. The ARDL and PMG methods were applied. The study results showed a positive relationship between FD and CO2 in both groups of countries; moreover it revealed a one-way causal correlation from FD to CO2. Another study (Khan,.& Butt, 2021) investigated the relationship between FD and CO2 in 184 countries during the period 1990 – 2017, using the GMM method. A negative relationship was revealed denoting that in those 184 countries, financial development had contributed to environmental sustainability. Conversely, a study carried out in China(Shen, et al.,2021) regarding the period 1980 - 2016 and using the ARDL model, found that financial development contributed to environment degradation in China.

A study (Bekhet, et al.,2017) concerning South- Asian economies and covering years ranging between1990 – 2014 also found a positive correlation between FD and CO2. Moreover, a causal relationship was observed, explaining that financial development increased carbon dioxide emissions. Similarly, a study carried out about Turkey (Katircioglu, et al.,2018) during the time span 1960 – 2014 found a positive relationship between FD and CO2; while Granger causality test confirmed a one-way causal relationship going from FD to CO2.

Conversely, a study (Oluwajana, et al.,2021) carried out on South Africa and covering the period 1980 – 2017 and using the ARDL, FMOLS and DOLS techniques and a causality test. Results underscored a negative relationship between FD and CO2 while the causality test depicted a one-way causal relationship from FD to CO2 both in the short run and the long run.

Using annual data over the time span 1970 – 2016 in Thailand, and applying the ARDL model and other techniques that study (Odugbesan, et al.,2021) concluded that no upswing in financial development had had a big effect on the level of emissions in Thailand.

2.3. Globalization and Carbon Dioxide Emissions

Although through many years, numerous studies have investigated the relationship between globalization and carbon dioxide emissions, there is no consensus as to the effect of GLO on CO2. For example, a study(Rahman, 2020) concerning the ten biggest energy consuming countries during the time period 1971 – 2013, and using both the FMOLS and DOLS techniques, concluded that GLO negatively influences CO2. In other words, the sudden surge of globalization has had a beneficial effect on the quality of environment. Furthermore, a one-way negative correlation from GLO to CO2 was revealed. Another study (Ahmed, et al.2021) covering 31 developed countries and 155 developing countries during the time span 1991 - 2018 also found a negative correlation between GLO and CO2, thus indicating that a higher level of globalization led to the mitigation of environmental degradation. Using the Driscoll-Kraay methodology and applying it to 23 African countries during the time period 1999 – 2017, a third study(Leal,.& Marques, 2021) similarly found a negative correlation between GLO and CO2. In addition, a study (He, et al. ,2021) using ARDL, the dual gap method and the causality test, reached the same conclusion; i.e., a negative correlation existed between GLO and CO2, and the causality relationship flowed in one way, from GLO to CO2.

A research study (Kirikkaleli, et al.,2021) inquired into the dynamic relationship between GLO and CO2 in Turkey during the years 1971 – 2016 using the ARDL and co-integration models and the causality test. The results confirmed the existence of a negative correlation between GLO and CO2, and a one-way causality relationship running from GLO to CO2. The same results were obtained by a study (Kihombo, et al.2021) investigating the economies of West Asia and the Middle East (WAME) during the period 1990 – 2017. Another study (Yuping, et al.2021) using the advanced time series, found that the rising level of globalization helped to mitigate environment degradation in Argentina.

3. The Study Model and Data Specifications

In this section, the study model construction, the estimation strategy and the data used for estimating the targeted relationship are presented.

3.1. Model Construction

Economic expansion may influence carbon dioxide emissions in three ways, namely through the scale effect, the composition effect and the technology effect. The scale effect considers that economic expansion tends to pollute the environment at the beginning of the expansion process given that increased production requires additional resources and energy consumption, thus yielding higher levels of pollution and wastes. On the other hand, the level of pollution and the amount of used resources depend on the relative importance of the different sectors of production in the economy. According to the composition effect, the structural evolution of the economy from the industrial sector as the main sector of production, towards the services sector is expected to reduce the detrimental impact of economic growth on the environment. The technology effect becomes apparent when a higher level of welfare is achieved allowing the country to adopt advanced technologies that support increased production while reducing emissions.

The exploitation of energy sources is constantly rising in parallel with the growing World population and the increasing economic growth and development; given that energy is a basic requirement for industrial production, transportation, household needs, etc. Moreover, with the ever expanding urbanization and increasing linkages within the global economy, energy consumption is bound to increase due to the surging cable and radio communications and the increasing travelling movement. However, increased energy consumption negatively affects the environment as well as people’s health, safety, life style and communications as proven by the World past experience.

On the other hand, financial development may contribute to the improvement of the quality of environment through promoting investment in green technologies and cleaner energy products. However, financial development may incentivize economic activities, leading to increased energy consumption and carbon dioxide emissions.

During recent years, scientists have inadequately focused on the different aspects of the relationship between energy consumption and globalization. From the theoretical point of view, this relationship is quite simple. As countries become more involved in globalization, their energy needs increase. This can be explained by the fact that it is generally expected that with the evolution of globalization, trade barriers will be relaxed and each country will be encouraged to increase its production, and consequently its national income. Higher levels of production and welfare require higher levels of energy consumption. Therefore, it is assumed that GDP and EC are positively correlated.

Based on this background, the present study endeavors to measure the short run and the long run effects of energy consumption, income level, financial development and globalization on environmental sustainability in Egypt. In addition, the non-linear hypothesis of the environmental Kuznets curve is being verified. In other words, the study investigates whether or not an income level may have different effects on environmental sustainability according to the scale of income.

The present empirical research used the data obtained from annual time series concerning Egypt, during the rather long time period extending from year 1990 to year 2020, with a total of 31 observations per year. The study sample was chosen based on the availability of data from the World Bank database.

Using the model of the study (Baydoun, &Aga, 2021), and based on the present study assumptions, the following general model in its linear form was applied to assess the effects of energy consumption, income, financial development, and globalization on environmental sustainability.

$$SE_t = C_t + \theta_1 RGDP_{C_t} + \theta_2 FD_t + \theta_3 GLO_t + \theta_4 EC_t + \sum_{k=1}^{K} \beta_k X_t^k + \epsilon_t \quad (1)$$

Where SE_t is the environmental sustainability of Egypt in the time period t, where t = 1, 2, .., n. In this study, environmental sustainability is represented by the level of carbon dioxide emissions, in conformity with the study of (Baydoun & Aga, 2021); so that a higher level of emissions reduces environmental sustainability, and vice versa. However the present study aims at obtaining a more comprehensive view of environmental sustainability through describing the level of emissions in three different ways: The scale, the density, and the damage of carbon dioxide emissions; whereas the previous study [40] used only the scale of emissions as a proxy for environmental sustainability. C is the constant term of the equation.

θ_1 to θ_4 represent the coefficients of the targeted independent variables, namely: The level of income (RGDP), the level of financial development (FD), the level of globalization (GLO), and the level of energy consumption (EC) respectively.

X_t^k is the vector of control variables which in turn express probable determinants of environmental sustainability other than the targeted variables. According to the current literature, industrial value added and the value of energy consumption of fossil fuel are included as control variables. Finally ϵ_t is the error term a usually defined.

Before adopting the above-mentioned model, we had to verify whether or not it correctly describes the targeted relationship. In other words, we had to check whether the relationship between the independent variables and the dependent variable takes the shape of a linear or a non-linear function. In order to achieve this objective, the auxiliary regression for non-linearity test- squared terms was used. The results showed that all the independent variables followed a linear path in their relationship with the variables that represented environmental sustainability, namely the scale, density and damage of carbon dioxide emissions; with the exception of the income level and financial development variables which had a non-linear relationship with the environmental sustainability variables. Therefore, the squared terms of these two independent variables were used in the study model instead of the simple terms.

Equation (2) represents the final study model.

$$SE_t = \beta_0 + \beta_1 RGDP_{C_t} + \beta_2 RGDP^2_{C\,t} + \beta_3 FD_t + \beta_4 FD^2_t + \beta_5 GLO_t + \beta_6 EC_t + \beta_7 IVA_t + \beta_8 FFEC_t + \epsilon_t \qquad (2)$$

In this second equation, the squared terms of RGDP and FD are used in order to determine the various effects of the levels of income and financial development on environmental sustainability. The two coefficients β_7 and β_8 measure the effect of the control variables, namely the industrial value added (IVA) and the value of fossil fuel energy consumption (FFEC) respectively.

Concerning the expected signs of the coefficients, it is generally assumed that increased production leads to environment degradation through the increased use of resources and energy. Therefore, the continuous growth of the Egyptian economy represents a real threat to the environment due to unsustainable development practices. Consequently, the relationship between RGDP and SE is expected to be positive; i.e. ß1 $= \frac{\partial SE}{\partial RGDP_C} > 0.$

Since a large ratio of energy consumption uses depends on non-renewable sources, the relationship between energy consumption and environmental sustainability is also expected to be positive:

$$ß_6 = \frac{\partial SE}{\partial EC} > 0$$

On the other hand, we expect a negative correlation between FD and SE: $ß\,3 = \frac{\partial SE}{\partial FD} < 0$; unless FD is environment unfriendly, then we would expect a positive correlation between these two variables:

$$ß3 = \frac{\partial SE}{\partial FD} > 0$$

Globalization has been included in the study to reflect the fact that GLO has boosted competitiveness through increasing the flows of goods and services, thus seriously jeopardizing the environment. In other words, we expect a positive correlation to exist between GLO and SE:

$$ß5 = \frac{\partial SE}{\partial GLO} > 0$$

However, if the practices instigated by globalization are environment friendly, then we would expect the correlation n between GLO and SE to be negative: $ß5 = \frac{\partial SE}{\partial GLO} < 0$.

Now in order to estimate the turning point of the income level curve and the financial development curve, we take the first differential derivative of each function then we equate it to zero, as follows:

$$\frac{\partial SE}{\partial RGDP_C} = β_1 + 2β_2 RGDP_{C}{}_{t-1}^{3} \qquad (3)$$

$$\frac{\partial SE}{\partial FD} = β_3 + 2β_4 FD_{t-1}^{3} \qquad (4)$$

By equating Equation (3) and Equation (4) to zero, the turning point of the income level curve and the financial development curve is obtained as follows:

$$RGDP_C{}^{*} = -\frac{β_1}{2β_2} \quad ; \quad FD^{*} = -\frac{β_3}{2β_4} \qquad (5)$$

3.2. The Study Data

The study relied on a wide span of variables with data outsourced from the World Bank database, (http://www.worldbank.org), covering the time period 1990 – 2020 in order to estimate the dynamic correlation between carbon dioxide emissions and the explanatory variables. The study data are the following:

Environmental sustainability (SE) is the dependent variable and is expressed as the pollution level and measured by three aspects of carbon dioxide emissions:

i. The scale of emissions, expressed as the average per capita amount of carbon dioxide emissions measured in metric tons (ES);

ii. The intensity of emissions (EI) as reflected by the carbon dioxide emissions index (expressed in kilograms per each US dollar of the gross domestic product value in 2010); and

iii. The damage of emissions (ED) measured by the index of the damage of carbon dioxide gas expressed as a percentage ratio of national income.

The independent variables:

i. Economic growth (RGDPc) is measured by the per capita real gross domestic product in local currency;

ii. Energy consumption (EC) is measured by per capita energy consumption;

iii. Financial development (FD) is represented by the amount of domestic credit advanced to the private sector as a ratio of GDP; and

iv. Globalization is measured by a composite index based on foreign direct investment (FDI), trade (Trade), and foreign portfolio flows (FPF).

Control variables in this study include the growth rate of industrial value added; and fossil fuel energy consumption as a ratio of total energy consumption.

Table A in the study Appendix includes a brief description and analysis of the study data and well as their sources and symbols.

Tables (1) and (2) below present the descriptive statistics for the variables and the correlation matrix between the variables during the study period, respectively.

Table (1): Descriptive statistics for variables, 1990 - 2020:

	Unit of measurement	Obs.	Mean	Median	Std. Dev.	Min	Max	Normality test
Dependent Variable:								
ES	(Metric tons per capita)	31	2.0465	2.1479	0.405	1.439	2.519	[3.9451]
EI	(Kg per US$ of GDP)	31	0.6956	0.6860	0.035	0.628	0.768	[1.9843]
ED	(% of GNI)	51	2.3293	2.3361	0.911	0.719	4.181	[1.0334]
Independent Variable:								
RGDPc	(Constant LCU)	31	28496	27429	6211	19655	39041	[2.4110]
FD	(% of GDP)	31	36.531	33.072	11.59	22.06	54.93	[3.3522]
GLO	n/a	31	-0.1143	-0.5457	1.253	-1.346	3.223	[14.429]***
EC	(Kg of oil per capita)	31	763.11	813.99	163.0	540.7	1012	[3.4165]
Control Variables:								
IVA	(annual % growth)	31	4.0842	4.6019	2.756	0.290	12.11	[1.8244]
FFEC	(% of total)	31	95.875	96.162	1.766	93.38	98.66	[2.9757]

Note: - *** indicate significance at 1%.

Table (2): Correlation matrix between variables, 1990 - 2020:

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ES	(1)	1							
EI	(2)	-0.1235 [-0.670]	1						
ED	(3)	0.3664 [2.121]**	0.2614 [1.458]	1					
RGDPc	(4)	0.9679 [20.77]***	-0.3252 [-1.852]*	0.7982 [9.275]***	1				
FD	(5)	-0.1965 [-1.079]	-0.1592 [-0.869]	0.6417 [5.857]***	-0.2085 [-1.148]	1			

GLO	(6)	0.1594 [0.869]	0.6633 [4.774]***	0.2316 [1.632]	-0.0171 [-0.092]	0.1221 [0.663]	1		
EC	(7)	0.9834 [29.16]***	-0.1291 [-0.701]	0.8252 [10.12]***	0.9692 [21.18]***	-0.2089 [-1.151]	0.1823 [0.998]	1	
IVA	(8)	-0.1995 [-1.096]	0.2650 [1.480]	-0.4225 [-3.25]***	-0.2475 [-1.376]	0.2783 [1.560]	0.5244 [3.316]***	-0.1698 [-0.928]	1
FFEC	(9)	0.9389 [14.69]***	-0.1899 [-1.042]	0.8361 [10.56]***	0.9481 [16.06]	-0.2915 [-1.641]	0.0226 [0.122]	0.9319 [13.84]	-0.3111 [-1.76]*

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

The afore-mentioned Table (1) and Figure (A) in the Appendix describe the main characteristics of the study variables. Concerning the dependent variables, Figure (A) shows that the scale of emissions followed an upward general trend thus pointing out to an increasing pollution damage; while emissions intensity followed a downward general trend. During the study period, the amount of emissions per capita increased from 1.56 metric tons to 2.50 metric tons. Consequently, the emissions' damage rose from 0.719% to 3.18% of national income, possibly reflecting the scale and the composition effects. In contrast, emissions intensity per US dollar of GDP declined from 0.754 kg to 0.657 Kg, possibly reflecting the technology effect through the adoption of energy saving techniques resulting in decreasing emissions per US dollar of GDP.

Regarding the independent variables, Figure (A) revealed a rising general trend of the income and energy consumption levels. During the study period, per capita income rose from 19655 Egyptian Pounds (EGP) per year to 39041 EGP per year, leading to the increase of per capita energy consumption from 540.7 kg to 1012 kg. On the other hand, financial development and globalization fluctuated around an average of 36.5% of GDP for the domestic credit advanced to the private sector; and a mean value of -0.5457 for the globalization level.

Control variables: Industrial value added realized an average growth rate of 4.08% during the study period. Fossil fuel energy consumption equaled an average of 95.9% of total energy consumption during the same period.

It is noteworthy that the time series of the Egyptian data, with the exception of the globalization level, followed a normal distribution, implying the fluctuation of those time series around their mean value.

Table (2) indicates that the signs of most of the correlation coefficients agree with the economic theory, as expected. It can be seen that the correlation of the independent variables with carbon dioxide emissions varies according to the used emissions index. Emissions scale and damage are strongly correlated to the income and the energy consumption levels. On the other hand, emissions intensity is strongly correlated to the globalization level only. This result confirms that the emissions' scale and damage are influenced by the scale and the composition effects. As the Egyptian economy grows in scale and evolves towards greater industrialization, the emissions scale increases with the growing levels of per capita income and per capita energy consumption. Emissions intensity is more influenced by the technology effect which is more related to the globalization level, since globalization is responsible for bringing up-to-date technologies into Egypt, either through direct foreign investment or technological imports.

3.3. Empirical methodology

The present study analyzes the time series and investigates the long run dynamic effects of energy consumption, income, financial development and globalization on environmental sustainability in Egypt, using co-integration and the Bounds Testing Approach., based on the Autoregressive Distributed Lag (ARDL) method. The causality direction of the relationship between the variables is verified using Granger Causality Test within the framework of the Vector Error Correction Model (VECM) and Toda-Yamamoto Granger Causality Test. Moreover, the study applies the impulse response function analysis and the variance components analysis of environmental sustainability. The following procedure was carried out.

3.3.1. Unit Root Test

The first step in our empirical analysis consists in verifying the stationarity of the time series and the degree of co-integration of each of them in the model in order to avoid spurious regressions. The unit root test is one of the best known methods for testing time series stationarity. However, as shown in Fuller (1976) the unit root test does not provide robust results; therefore, it is advisable to use several tests in this concern. The present study applied two of the most widely used tests in empirical research, namely the Augmented Dicky Fuller (ADK) and the Phillips Perron (PP) tests, to prove the robustness of the results.

Table (B) in the Appendix displays the stationarity results. The ADF and the PP tests both agree that all the variables were non-stationary at the level, but became stationary when the first difference was used; i.e. they became integrated of the I(1) degree; with the exception of the index of the globalization level which proved to be stationary at the level, i.e. it was integrated of the I(0) degree. Since the results show that we have a mixture of variables some being stationary at the level and others being stationary at the fist difference, or a mixture of I(0) and I(1), then there is need for using the ARDL technique.

3.3.2. The Co-integration Test using the ARDL technique:

In order to carry out the co-integration test according to the ARDL procedure, we have to verify whether or not there is a long run relationship- co-integration - between the study variables within the framework of the Unrestricted Error Correction Model (UECM). To do this, we compare the calculated F-stat with the tabulated values within the critical bounds. If the calculated F-stat is greater than the upper critical bound, then the null hypothesis is rejected and the alternative hypothesis is accepted meaning that a co-integration relationship exists between the variables. If the estimated value of the F-statistic is smaller than the lower critical bound, the null hypothesis is accepted, meaning that there is no co-integration relationship between the variables. Finally, if the estimated F-stat falls between the upper and the lower bounds, then we cannot decide whether or not there is a co-integration relationship between the variables. Table (3) shows the results of the co-integration test using the ARLD model.

Table (3): Bounds testing results:

Regressors: (k = 8)		F-statistic
$ES_t = f(RGDP_{C_t}, RGDP^2_{C_t}, FD_t, FD^2_t, GLO_t, EC_t, IVA_t, FFEC_t)$, ARDL (4, 1, 1, 0, 1, 1, 1, 1, 1)		94.9585***
$EI_t = f(RGDP_{C_t}, RGDP^2_{C_t}, FD_t, FD^2_t, GLO_t, EC_t, IVA_t, FFEC_t)$, ARDL (2, 0, 0, 0, 1, 1, 1, 0, 1)		5.20643***
$ED_t = f(RGDP_{C_t}, RGDP^2_{C_t}, FD_t, FD^2_t, GLO_t, EC_t, IVA_t, FFEC_t)$, ARDL (3, 0, 3, 2, 3, 1, 3, 3, 1)		3.75192**
Significant level	Critical values bound	
	Lower Critical Bounds (I0)	Upper Critical Bounds (I1)
10%	1.85	2.85
5%	2.11	3.15
1%	2.62	3.77

Note: - ***, ** indicate significance at 1% and 5% respectively.

Table (3) indicates that the estimated F-stat for the three models (the scale, intensity and damage of the emissions) is greater than the corresponding upper critical bound (UCB). Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted, meaning that a long run equilibrium relationship exists between energy consumption, income, financial development, globalization and environmental sustainability. In other words, there is a co-integration relationship at the 1% significance level. Therefore, we can proceed further with our analysis, in order to estimate the long run and the short run coefficients.

Estimation of the short run and the long run models using the ARDL technique

Given the co-integration relationship between the variables of the study models, we need to estimate their long run relationship and the error correction model. To do this, the estimated residuals, lagged with one time period Ɛt-1 and obtained from the long run relationship are used. The error correction model (ECM) plays two major roles: Firstly, the estimation of the short run coefficients; and secondly, the estimation of the error correction term (ECT) represented by the coefficient ɣ in the above-mentioned equation. The error correction term measures the speed of the disequilibrium adjustment in the short run towards the realization of the long run equilibrium. The ECT must be negative and significant to prove that the relationship is stable in the long run; i.e. that the error correction mechanism is inherent in the model.

But before applying the ARDL technique to estimate the coefficients, the validity and robustness of the models must be checked according to the various statistical, economic and econometric criteria in order to make sure that the models are free from measurement problems and that the obtained results are reliable. The signs of the diagnostic tests are shown in Table C in the Appendix and confirm that the estimated empirical models are free from the problems of serial correlation between the residuals, and free from heteroscedasticity. Moreover, the testing results indicate that the residuals display a normal distribution and that the models are adequately described (i.e. the functions representing the model are correct). In addition, it is confirmed that the used data are free from any structural change (i.e. there are no leaps or sudden changes in the data through time), given that the cumulative sum chart (CUSUM) and the CUSUM of Squares fall within the critical bounds at the 5% significance level.

We conclude that the used model enjoys stability and harmony between the short run and the long run results. Furthermore, the key regression statistics show that the adjusted coefficient of determination (R2) adopts a high value exceeding 95% indicating the high explanatory strength of the models.

In addition, the estimated Durbin-Watson statistic (DW-stat) was found greater than the tabulated DW value of 1.977 thus indicating the absence of a serial correlation between the residuals. Similarly, the Fisher test results confirm the rejection of the null hypothesis and the acceptance of the alternative hypothesis indicating that the used models as a whole are statistically significant at the 1% level.

Based on the results of the aforementioned tests, the validity of the used models for estimating the short run and the long run relationship between the variables is confirmed. Therefore, we proceed with the analysis as demonstrated in Table (4).

Table (4): Energy Consumption, Economic Growth, Financial Development and Environmental Sustainability in Egypt: Empirical results:

Dependent Variable: ES & EI & ED

Method: ARDL with HAC standard errors

Model selection method: Schwarz criterion (SIC)

Variable	Model (1)	Model (2)	Model (3)
	ES	EI	ED
Long-run coefficients:			
RGDPc	0.00022 [137.5]***	2.03E-6 [0.416]	0.00061 [3.221]***
RGDPc_squared	-3.28E-9 [-184.9]***	-3.2E-10 [-4.459]***	-1.09E-8 [-4.312]***
FD	-0.01589 [-14.31]***	-0.01156 [-6.061]***	-0.21219 [-3.701]***
FD_squared	0.00012 [8.463]***	0.00014 [5.752]***	0.00238 [3.512]***
GLO	0.01483 [8.434]***	0.01086 [2.473]**	0.07473 [0.874]
EC	0.00098 [20.43]***	0.00048 [5.716]***	-0.00158 [-0.437]
IVA	-0.00222 [-4.096]***	-0.00039 [-0.322]	-0.11447 [-3.773]***
FFEC	0.01541 [7.572]***	0.01036 [1.871]*	0.08242 [1.465]
Constant	-3.31253 [-17.88]***	-0.21620 [-0.439]	-8.14404 [-1.876]*
Error correction coefficient:			

φ_i	-0.03192 [-4.013]**	-1.35729 [-9.545]***	-0.76946 [-7.436]***
Short-run coefficients:			
ES (-1)	-3.01749 [-19.92]***	-1.35729 [-5.882]***	-0.76946 [-4.998]***
RGDPc	0.00067 [17.45]***	2.75E-6 [0.266]	0.00047 [2.719]**
RGDPc_squared	-9.90E-9 [-18.80]***	-4.4E-10 [-2.829]**	-8.40E-9 [-3.021]***
FD	-0.04794 [-9.115]***	-0.01569 [-4.418]***	-0.16327 [-2.361]**
FD_squared	0.00035 [6.446]***	0.00018 [4.362]***	0.00183 [2.199]**
GLO	0.04476 [6.801]***	0.01474 [1.972]*	0.05750 [0.669]
EC	0.00295 [20.12]***	0.00066 [3.881]***	-0.00122 [-0.382]
IVA	-0.00669 [-3.033]***	-0.00053 [-0.372]	-0.08808 [-2.945]***
FFEC	0.04651 [7.734]***	0.01406 [1.453]	0.06342 [0.746]
Constant	-9.99553 [-16.92]***	-0.29344 [-0.339]	-6.26648 [-0.961]
		key regression statistics	
Obs.	31	31	49
R-squared	99.9%	95.03%	97.5%
Adjusted R-squared	98.1%	88.4%	93.9%
DW stat.	2.8305	2.3913	2.2420
Fisher test	[6796.5]***	[14.344]***	[27.007]***

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Table (5): Sasabuchi–Lind–Mehlum test for an inverse U-shaped relationship:

		Model (1)		Model (2)		Model (3)	
		RGDPc	FD	RGDPc	FD	RGDPc	FD
X_i	$\hat{\beta} =$	0.00022 [137.5]***	-0.01589 [-14.31]***	2.03E-6 [0.416]	-0.01156 [-6.061]***	0.00061 [3.221]***	-0.21219 [-3.701]***
X_i^2	$\hat{\gamma} =$	-3.28E-9 [-184.9]***	0.00012 [8.463]***	-3.2E-10 [-4.459]***	0.00014 [5.752]***	-3.28E-9 [-4.312]***	0.00238 [3.512]***
Interval	$X_{l\,(min)} =$	9324.16	10.2777	9324.16	10.2777	9324.16	10.2777
	$X_{h\,(max)} =$	39040.6	54.9311	39040.6	54.9311	39040.6	54.9311
Slope at X_l	$\hat{\beta} + 2\hat{\gamma}X_l =$	1.62E-9 [4.393]***	-1.35E-2 [-1.963]*	-4.01E-6 [-0.923]	-8.79E-3 [-4.236]***	6.14E-4 [2.368]***	-2.12E-1 [-4.321]***
Slope at X_h	$\hat{\beta} + 2\hat{\gamma}X_h =$	-3.41E-5 [-5.199]***	-3.03E-3 [-2.345]**	-2.33E-5 [-3.921]***	3.27E-3 [3.968]***	-2.37E-4 [-5.215]***	2.38E-3 [3.296]***
Sasabuchi test (t-value)		[1.093]	N/A	N/A	[6.519]***	[1.226]	[3.596]***
Extremum Point	$-\hat{\beta}/(2\hat{\gamma}) =$	33841.5	67.8889	N/A	42.8259	28165.1	44.6332
		Extremum inside interval	Extremum outside interval	N/A	Extremum inside interval	Extremum inside interval	Extremum inside interval

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Table (4) displays the results of the three regressions corresponding to the three emissions variables. The first regression pictures the relationship between energy consumption, income level, financial development and globalization, on one hand, and the scale of emissions, on the other hand. The second regression shows the relationship between these independent variables and the intensity of emissions and the third regression is concerned with the relationship between the independent variables and the damage caused by the emissions. Long run results indicate that energy consumption and globalization levels had a positive effect on the scale and intensity of emissions whereas they had no influence on the emissions' damage.

Regressions (1) and (3) trace a non-linear, inverse U-shaped relationship between income levels and the scale and damage of emissions. As the income level increases, the scale and the damage of emissions increase. But once income reaches a given level, income increases lead to a reduction of the scale and the damage of emissions. This proves the applicability of the environmental Kuznets curve to Egypt. On the other hand, Regression (1) shows that the relationship between income levels and the intensity of emissions is linear and negative reflecting the fact that as the income level rises, the State becomes able to adopt cleaner technologies.

In order to verify the non-linearity of the relationship between income levels and the scale and damage of emissions, i.e. the validity of the EKC hypothesis for Egypt, the Sasabuchi-Lind-Mehlum test was carried out. The test results are listed in Table (5). Regressions (1) and (3) show that the test statistic is statistically insignificant, leading to the acceptance of the null hypothesis thus confirming the inverse U-shaped relationship between the above-mentioned variables. Moreover, the turning point falls within the bounds of the actual income level data. It is therefore deduced that the inverse U-shaped relationship is real and not spurious. We also note that the turning point of the income level-scale of emissions curve occurs when the per capita annual real income level equals

33841.5 EGP, while the turning point for the damage of emissions occurs when the income level reaches 28165.1 EGP. In other words, the income level effect on the scale of emissions becomes negative when the per capita real income level exceeds 33841.5 EGP; while the income level effect on the damage of emissions becomes negative when the per capita real income level exceeds the 28165EGP threshold; i.e., at a lower income level than that required in the case of the scale of emissions.

Similar results are found concerning financial development. From the three relevant regressions, we deduce that a non-linear relationship exists between financial development, on one hand, and the scale, intensity and damage of the emissions, on the other hand. Furthermore, this relationship is represented by a U-shaped curve, indicating that financial development has a negative effect on the three measures of carbon dioxide emissions; however beyond a certain level of financial development, this effect becomes positive.

Regression (1) in Table (5) reveals that the U-shaped relationship between financial development and the scale of carbon dioxide emissions is deceptive, since the turning point which equals 67.89% lies beyond the range of actual data, given that the level of financial development in Egypt did not exceed 54.9% of GDP. On the other hand, the U-shaped relationship between the level of financial development and the intensity and damage of the emissions – as apparent in Regressions (3) and (4) – is real since the turning point falls within the range of actual data. The test statistic (t-value) was found significant in Regressions (2) and (3), implying the rejection of the null hypothesis of an inverse U-shaped relationship, and the acceptance of the alternative hypothesis confirming the existence of a U-shaped relationship. The minimum values (turning points) of the level of financial development equaled 42.8% for the intensity of emissions, and 44.6% for the damage of emissions.

Control variables: The increase of the industrial value added had a negative effect on the scale and the damage of emissions, but no effect whatsoever on the intensity of emissions. Meanwhile, the ratio of fossil fuel energy consumption had a positive effect on the scale and intensity of emissions. The short run results did not differ from the long run results although the short run effects were stronger. The one-year lagged dependent variables had a negative effect reflected as a declining general trend towards the reduction of emissions and hence, the realization of environmental sustainability. Finally, the error correction model coefficient ECM (- 1) appeared negative and significant in the three regressions, thus proving that the error correction mechanism existed in the three regressions, leading to the stability of the relationship between the short run and the long run.

Discussion of the results

In this section, the above-mentioned results of the empirical research are discussed in detail. In order to investigate the impact of energy consumption (EC), the income level (RGDPc), financial development (FD) and globalization (GLO) on carbon dioxide (CO2) emissions in Egypt, this study relied on the ARDL technique.

The ARDL results reveal that the rising income level increases environmental degradation in Egypt. This simply means that the Egyptian economy is boosting economic growth at the expense of the quality of the environment. In other words, relatively high growth rates and rapid economic expansion are driving up energy consumption in Egypt and hence are leading to increased environmental degradation. On the other hand, findings confirm that the EKC hypothesis is applicable to Egypt, thus indicating that the Egyptian economy is following the right track towards environmental sustainability. For as the income level increases, greener technologies can be adopted leading to the reduction of the intensity of emissions.

These results are in line with the findings of (Zhang, et al. ,2021) who concluded that the sudden surge in carbon dioxide emissions in Malaysia was due to the leap in economic expansion. Furthermore, the studies of Su, et al. (2018) concerning Brazil, (Tufail, et al. ,2021) regarding strongly decentralized economies, and (Yuping, et al.,2021) about Argentina also deduced that a positive and mutual relationship existed between economic growth and carbon dioxide emissions.

Moreover, the present study revealed a positive and mutual relationship between energy consumption and the scale and intensity of carbon dioxide emissions both in the short and the long run. This is of course an expected result since energy consumption is necessary for economic expansion, although it increases environmental degradation. Therefore, using renewable energy sources would help to reduce the detrimental impact of economic expansion in Egypt. This result agrees with (He, et al., 2021) who observed a positive correlation between energy consumption and carbon dioxide emissions in Mexico. The study of (Ramzan, et al. ,2021) covering a selected group of Latin American countries reached a similar conclusion.

The results of the present study also agree with the findings of (Kirikkaleli, et al.,2021) concerning India, and (Udemba, et al. ,2021) about Chili.

Both the short run and the long run correlation between financial development and the intensity and damage of carbon dioxide emissions is important and non-linear. This result is not surprising, since financial development is not expected to reduce environmental degradation in emerging economies such as Egypt, where the structural development of the financial sector is still in its early stages. Comparable results were obtained by (Oluwajana, et al. , 2021) regarding South Africa, and by (Khan.& Butt, 2021) in Malaysia where a negative correlation was revealed between FD and CO2.

Moreover, a mutual negative relationship existed between globalization and the scale and intensity of CO2 emissions, thus indicating that globalization plays a vital role in reducing CO2 emissions in the Egyptian economy. One of the probable reasons underlying this negative relationship is that through trade, globalization allows for the adoption of more advanced production techniques along with the increase of the economic activity. According to the study of (Koengkan, & Fuinhas, 2020) concerning the Andes countries, such as Colombia, Peru, Bolivia, and Ecuador, the free trade policy incentivizes industrialization through the scale, the comparative advantage and the technology effects. Trade boosts investment which in turn drives up economic activity and energy consumption, eventually increasing environmental degradation. This result is in agreement with the conclusions reached by (Ahmed, et al. ,(2021) about Japan, and (Zaidi, et al. ,2019) concerning the member economies of the Asia- Pacific Economic Cooperation

(APEC); and (Usman, et al. ,2020 a) regarding gas emissions in 15 countries.

However, this result contradicts the findings of (Usman, et al. 2020 b) concerning South Africa, and (Adebayo & Acheampong 2021) about Australia, and (Kirikkaleli, et al. ,2021) who discovered a positive correlation between globalization and carbon dioxide emissions.

3.3.3. Causality tests

3.3.3a. Granger causality test within the Vector Error Correction Model (VECM)

This step follows the verification of the existence of a co-integration leading to a long run relationship between the study variables and implying a causality relationship, at least in one direction. However, in order to determine the direction of the causality relationship, Granger causality test is used regarding both the short run and the long run, within the framework of the Vector Error correction Model (VECM). The direction of the causality relationship of the equations in the short run is determined based on the statistical significance of the first difference coefficients of the independent variables using the F-test; whereas the direction of the causality relationship in the long run is determined through calculating the statistical significance of the coefficient of the error correction term, using the T-test.

Table (6): Granger Causality in Vector Error Correction Model (VECM):

Model	Dependent Variable	Short-run causality (F test)				Long-run causality (t test)
		RGDPc	FD	GLO	EC	ECTt-1
(1)	ES	[0.1851] (0.833)	[0.3889] (0.684)	[1.1676] (0.336)	[0.2010] (0.819)	[-0.4430] (0.664)
(2)	EI	[0.0045] (0.996)	[3.0294] (0.077)*	[1.9174] (0.179)	[5.3486] (0.017)**	[-1.4879] (0.002)***
(3)	ED	[0.6306] (0.538)	[0.9068] (0.413)	[1.2446] (0.301)	[3.1386] (0.056)*	[0.0525] (0.049)**

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Table (6) shows that the causality relationship runs from the variables of energy consumption, the income level, financial development and globalization to environmental sustainability , both in the short run and the long run. The opposite direction was not revealed in the abovementioned table. On the other hand, no causality relationship was found, neither in the short run nor the long run, heading from the variables of energy consumption, the income level, financial development and globalization towards the scale and damage of emissions; with one exception, as a causality relationship was found running from energy consumption to the damage of emissions. Conversely, the t-statistic revealed a long run causality relationship going from the vector of variables X (energy consumption, income, financial development, and globalization) to the intensity of emissions. Similarly, the F-statistic depicted a short run causality relationship going from financial development and energy consumption to the intensity of emissions.

3.3.3b. Toda- Yamamoto Granger Causality Test

Toda and Yamamoto (1995) suggested an interesting, although simple procedure to perform the causality test. That procedure required the evaluation of the augmented VAR that includes the corresponding distribution of the modified Wald statistics (the approximated X2 distribution), as that test is adequate for dealing with the characteristics of co-integration. According to (Zapata & Rambaldi 1997), the main advantage of the Todo-Yamamoto procedure is the possibility of carrying out Granger causality test within the framework of the VAR model without need for previously testing the variables for the existence of co-integration, or even for transforming the VAR model into the error correction model (ECM). Moreover, the suggested testing procedure does not require that all the variables be stationary at the same rank, whether at the level or at the first difference. In other words, that procedure allows the performance of the causality test whether the variables are stationary at I(0), I(1) or even I(2), and whether or not they are co-integrated.

Table (7): Toda-Yamamoto Granger Causality Test:

Model	Dependent Variable	Direction of causality (Chi-sq)				
		RGDPc	FD	GLO	EC	All
(1)	ES	[11.791] (0.019)**	[4.5511] (0.337)	[12.547] (0.014)**	[2.4957] (0.645)	[30.437] (0.016)**
(2)	EI	[10.393] (0.034)***	[1.2749] (0.866)	[12.885] (0.012)**	[3.0719] (0.546)	[57.792] (0.000)***
(3)	ED	[1.5367] (0.674)	[6.2299] (0.101)	[5.1115] (0.164)	[6.2208] (0.101)	[22.933] (0.028)**

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Similar to the results displayed in Table (6), Table (7) reveals a causality relationship going from the four variables (energy consumption, income, financial development and globalization) to environmental sustainability. The opposite causality direction is not apparent in Table (7) but will be discussed in the following analysis. The results of the long run causality tests can be broadly explained as follows:

Scale of emissions: The Chi-square statistic indicates the existence of a long run causality relationship flowing only from the income level and globalization variables to the scale of emissions at the 5% significance level. Moreover, the Chi-square statistic points out to a long run causality relationship going from energy consumption, income, financial development and globalization as a whole to the scale of emissions. An inverse long run causality relationship was also found heading from the scale of emissions to financial development and globalization only.

Intensity of emissions: The Chi-square statistic underscores the existence of a long run causality relationship flowing only from the income level and globalization variables to the intensity of emissions at the 5% significance level. Moreover, the Chi-square statistic points out to a long run causality relationship going from energy consumption, income, financial development and globalization as a whole to the intensity of emissions. An inverse long run causality relationship was also found heading from the intensity of emissions to globalization only.

Damage of emissions: The Chi-square statistic indicates the absence of any long run causality relationship going from any of the four variables taken separately to the damage of emissions. However, the Chi-square statistic denotes a long run causality relationship going from the four variables (energy consumption, income, financial development, and globalization) taken as a whole to the damage of emissions. On the other hand, no long run causality relationship was found running from the damage of emissions to any of the four variables (energy consumption, income, financial development, globalization) taken separately.

From the above-mentioned analysis, we conclude that a mutual long run causality relationship exists between the globalization level and the scale and the damage of emissions; while a one-way long run causality relationship runs from the income level to the scale and intensity of emissions. In addition, a one-way long run causality relationship flows from the scale of emissions to the financial development level.

3.3.4. Impulse Response Function and the Variance Components Analysis

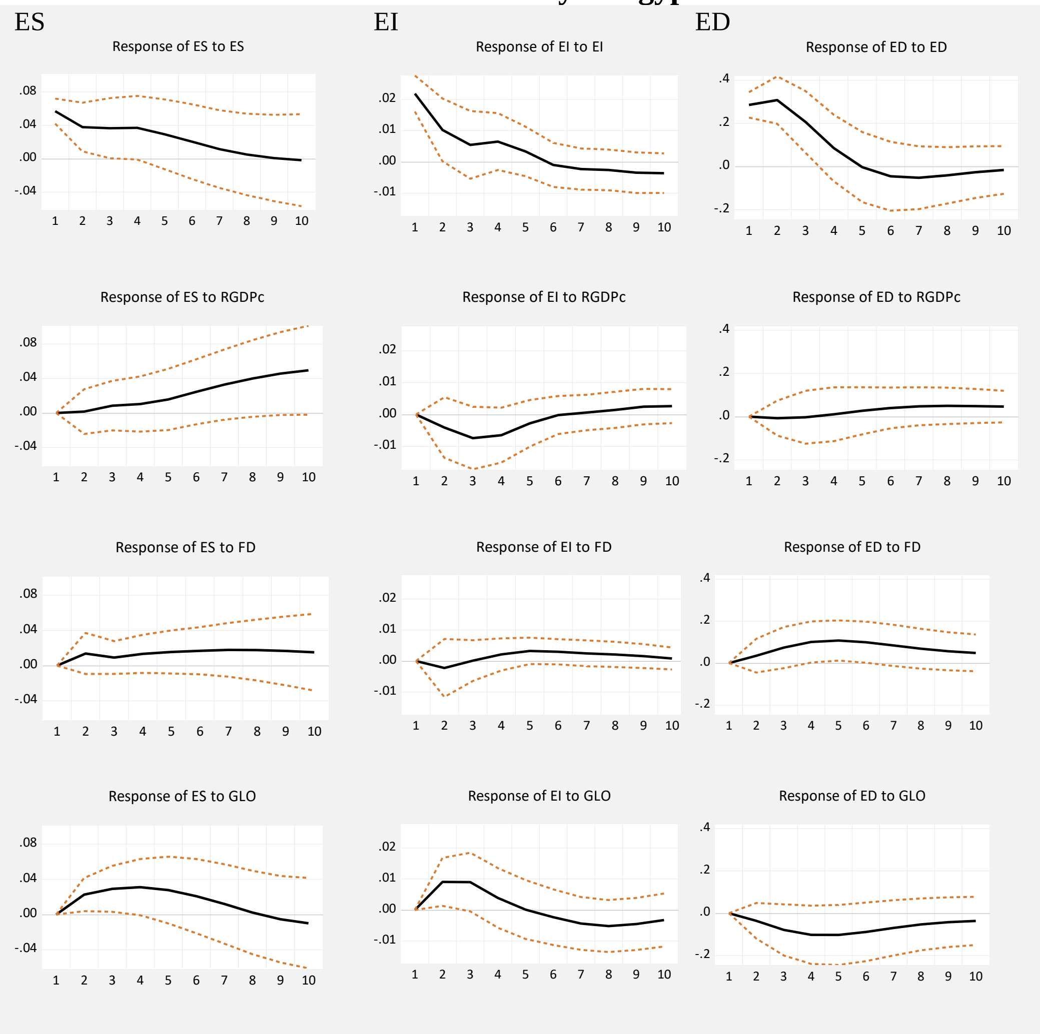
3.3.4a. Impulse Response Function (IRF)

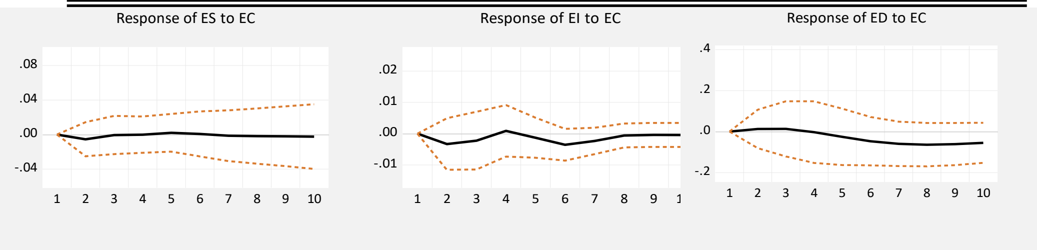
Impulse response functions, also called reaction functions, are one of the important applications of the VAR models. These functions allow us to identify the effect of a shock (an impulse) received by an endogenous variable inside the VAR model or the VECM, on the current and future values of the other endogenous variables in the model. In addition, these functions help us to determine the scattered effects of the impulse, i.e., the time lags that will elapse before the impact of the impulse vanishes and this happens when the impulse response function becomes equal to zero. Hence the impulse response function is a method for describing the dynamic behavior of the model.

In the present study, the reaction functions were estimated in order to assess to what extent environmental sustainability is influenced by various impulses in energy consumption, income level, financial development, globalization and environmental sustainability itself; and to measure the time span needed for the impulse effect to vanish, over a time period ranging from one year to ten years, which enables us to differentiate between the short run and the medium run.

In Figure (1) below, the horizontal axis measures the number of years elapsed after environmental sustainability receives the impulse, while the vertical axis measures the response level of environmental sustainability (as a percentage) to the impulse.

Figure (1): Impulse response functions for Environmental Sustainability in Egypt:





The charts in Figure (1) show that environmental sustainability is influenced by the deviation of the ES variable itself, in addition to the deviation of the EC, GDPc , FD, and GLO variables (by the value of one standard deviation).

Environmental sustainability: The impulse incurred by the lagged values of environmental sustainability is reflected by the impulse response function of ES during the first year, whereas the response to the other variables is not strong. Moreover, the response of ES to its own impulse tends to decline gradually though time until it vanishes. We note that an impulse in the scale of emissions tends to vanish in the ninth year. An impulse in the intensity of emissions vanishes in the sixth year, although the impulse keeps following a downward course causing an increasing negative impulse. The impulse in the damage of emissions vanishes in the fifth year, but follows a similar course as that of the intensity of emissions, eventually causing a negative impulse until it finally vanishes in the tenth year.

Income level: An impulse in the income level in Egypt has a positive and continuously rising effect on the ES indexes; although a negative and declining effect on the intensity of emissions is observed at the beginning, turning to a rising general trend starting the third year after the occurrence of the impulse.

Financial development: An impulse to the financial development level results in a response curve of environmental sustainability of an almost inverse U-shaped form. The curve follows an upward trend until the fifth year then gradually follows a declining course until it vanishes through time.

Globalization: The response of the environmental sustainability function to an impulse in the globalization level depends on the concerned ES variable. Hence, the impulse response function of the scale of emissions has the shape of an inverse U with the turning point occurring in the third year, and the impulse effect vanishing in the eighth year; while the response curve of the damage of emissions is U-shaped, following a declining trend until the fifth year, then gradually rising and tending to vanish in the tenth year. On the other hand, the response curve of the intensity of emissions is an inverse S-shaped, firstly adopting an inverse U-shape then turning into a U shape starting the fifth year.

Energy consumption: The impulse in the energy consumption variable is the least influential on environmental sustainability as its effect tends to gradually vanish either in the third year concerning the scale of emissions or in the fourth year for the intensity of emissions; whereas the effect of the impulse in EC starts to appear on the damage of emissions function only after the fourth year then it gradually increases in a similar way as seen in the case of an impulse in the income level.

Generally speaking, the analysis of impulse response functions shows that environmental sustainability in Egypt is influenced by impulses in energy consumption, income level, financial development and globalization in various degrees. The greatest impact results from an impulse in environmental sustainability itself, followed by an impulse in globalization.

The smallest and most rapidly vanishing effect is due to an impulse in energy consumption. The lasting effect of an impulse ranges from a minimum of three years to a maximum of ten years. Most importantly, the effect of all impulses tends to vanish through time – although at different rates – except for the income level impulse which leads to deep structural changes that leave the economy unable to go back to its former position.

3.3.4b. Variance Decomposition Analysis

Another way to identify the dynamic behavior of the study model consists in analyzing the variance of the errors in predicting environmental sustainability in order to determine the relative importance of each variable in explaining that variance. In other words, the variance decomposition analysis aims at measuring the contribution of random impulses in the model variables to the future fluctuations of environmental sustainability.

The variance decomposition analysis is therefore a method for describing the dynamic behavior of the model through measuring the effect of impulses in its variables through time. To achieve this goal, the error of each variable is decomposed into parts, each part corresponding to one of the model variables. To put it differently, the variance of the environmental sustainability error is due to the unpredicted impulses in the variables of energy consumption, income level, financial development, and globalization during the prediction time span.

Tables (D), (E), and (F) in the Appendix indicate that environmental sustainability itself explains 100% of the variance components in the first period; this happens when an impulse equal to one standard deviation occurs in environmental sustainability. The ES variance component then gradually declines to reach 38.2% for the scale of emissions, 59.5% for the intensity of emissions, and 63.8% for the damage of emissions after the elapse of ten years. Thus the lagged impulses occurring to environmental sustainability become the most important factor explaining the variance in environmental sustainability, both in the short run and the long run.

The other variables explained only a minor part of the ES variance, not exceeding the ceiling of 36% in most cases. For instance, globalization was the most important factor (when the effect of the scale of emissions itself is excluded) explaining 24.9% of the variance of the scale of emissions in the short run (five years), followed by globalization (5.5%), income (3.4%), and finally energy consumption (0.27%). However in the long run (ten years), the income level becomes the most important variable (after the scale of emissions variable itself) explaining the variance of the scale of emissions, at the ratio of 35.8%, against 16.6% for globalization. Financial development and energy consumption were responsible for only marginal ratios in ES variance explanation.

Appendix:

Table (A): Data description & Data source:

Acronym	Description	Source
ES	Emissions Scale: Measured by the index of carbon dioxide emissions (per capita CO_2 emissions in metric tons). These emissions result from the combustion of fossil fuel and the cement industry. They include CO_2 emissions resulting from the consumption of solid, liquid and gaseous kinds of fuel and from gas combustion.	WBI
EI	Emissions Intensity: Expressed by the index of	WBI

	carbon dioxide emissions (measured in Kg per each US dollar of gross domestic product – 2010 value). This index reflects the intensity of CO2 emissions, i.e. the quantity of emissions issued to obtain one US dollar worth of production.	
ED	Emissions Damage: Expressed as the damage resulting from CO2 emissions and measured as a percentage of national income. This damage is calculated by multiplying 20 US dollars (the damage unit in US$ in 1995 value) by carbon dioxide emissions in metric tons.	WBI
RGDPc	Income level: Expressed as the per capita real gross domestic product (in fixed prices of local currency). It is calculated by dividing the real gross domestic product by the number of inhabitants in mid-year.	WBI
FD	Financial development level: Measured by the local credit advanced to the private sector and expressed as a percentage of GDP. It includes the credit amounts advanced to the private sector by financial institutions and other corporations, in the form of loans, the purchase of unlisted securities, commercial credits and the other debit accounts creating reimbursement claims.	GFD
GLO	Globalization level: Measured by a composite index including three subsidiary indexes covering direct and indirect foreign investment and international trade. The following indexes were used in order to calculate the globalization level: Foreign direct investment, net cash inflows (% of GDP), foreign portfolio investments, bonds (public and guaranteed by the government, and private and unguaranteed, as a %of GDP), and international trade (% of GDP). This composite index was calculated according to the Principal Components Analysis (PCA) method.	WBI
EC	Energy consumption or Per capita consumption of	WBI

	petroleum equivalent (in Kg): Energy consumption refers to the consumption of primary energy before it is processed into the other end-user fuel products. It is equal to the original production plus imports and stock changes and minus exports and fuel quantities supplied to the ships and airplanes engaged in international transport activities.	
IVA	Industrial value added (annual percent rate of growth): The industrial value added is defined as the net product of the industrial sector. It is obtained by adding all the outputs and subtracting all the intermediary inputs. No discounts are made for the depreciation of industrialized products or for the depletion or degradation of natural resources. The industrial value added corresponds to Sections 10 to 45 of the International Standard Industrial Classification that include the realized value added in mining, processing industries, construction, and electricity, water and natural gas supplies.	WBI
FFEC	Fossil Fuel Energy Consumption (as a percent ratio of the total energy consumption). Fossil fuel includes coal, oil, petroleum, and natural gas products.	WBI

Note: - WBI; World Bank Indicators.
- GFD; Global Financial Development.

Table (B): Unit root test results:

Variables	Augmented Dickey-Fuller			Phillips-Perron			Results
	Intercept	Intercept & trend	None	Intercept	Intercept & trend	None	
ES	-0.5067 (0.876)	-1.2859 (0.872)	2.5197 (0.996)	-0.5886 (0.859)	-1.6809 (0.735)	2.0061 (0.982)	I(1)
D(ES)	-4.5005 (0.001)***			-4.5215 (0.000)***			
EI	-2.3322 (0.169)	-2.3399 (0.401)	-0.8055 (0.359)	-2.2949 (0.180)	-2.3717 (0.386)	-0.9513 (0.297)	I(1)
D(EI)	-5.4966 (0.000)*			-5.4979 (0.000)*			

	**			**			
ED	-2.1751 (0.218)	-3.1100 (0.115)	-0.0905 (0.648)	-1.7999 (0.376)	-2.4113 (0.369)	0.2673 (0.759)	
D(ED)	-4.8159 (0.000)***			-4.7790 (0.000)***			I(1)
RGDPc	0.3759 (0.979)	-2.0772 (0.545)	3.1439 (0.999)	0.9307 (0.995)	-2.2575 (0.449)	6.3498 (1.000)	
D(RGDPc)	-4.4349 (0.001)***			-3.9724 (0.003)***			I(1)
FD	-1.9618 (0.302)	-0.7230 (0.966)	-0.0062 (0.656)	-1.6603 (0.445)	-1.1626 (0.907)	-0.2346 (0.597)	
D(FD)	-3.2564 (0.023)**			-5.8256 (0.000)***			I(1)
GLO	-3.1073 (0.033)**			-2.6449 (0.091)*			I(0)
EC	-0.4404 (0.894)	-2.2235 (0.466)	3.3794 (0.999)	-0.4485 (0.892)	-2.4755 (0.338)	3.0722 (0.999)	
D(EC)	-6.3090 (0.000)***			-6.3116 (0.000)***			I(1)
IVA	-3.8045 (0.005)***			-3.8241 (0.005)***			
FFEC	-0.3949 (0.898)	-3.6041 (0.046)**		-0.0383 (0.948)	-3.5302 (0.054)*		I(1)
Critical Values		ADF			PP		
%1	-3.7696	-4.4407	-2.6743	-3.7529	-4.4163	-2.6694	
%5	-3.0049	-3.6329	-1.9572	-2.9981	-3.6220	-1.9564	
%10	-2.6422	-3.2547	-1.6082	-2.6388	-3.2486	-1.6085	

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Table (C): Diagnostic Tests used in the study models:

Problems	Tests used	Model (1)	Model (2)	Model (3)
Heteroskedasticity	Breusch-Pagan-Godfrey	0.65106 (0.779)	1.19870 (0.381)	0.84628 (0.661)
Serial Correlation	Breusch-Godfrey Serial Correlation LM	6.79850 (0.077)*	1.66123 (0.238)	1.28287 (0.303)
Normality	Jarque-Bera	0.68021 (0.712)	1.32302 (0.516)	0.89473 (0.639)
Function Form	Ramsey RESET test for specification	7.09959 (0.056)*	0.56978 (0.466)	1.36317 (0.258)
Linearity	Auxiliary regression for non-linearity	28.4088 (0.000)***	22.0192 (0.000)***	19.6709 (0.003)***

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

Table (D): Variance Decomposition of ES:

Period	S.E.	ES	RGDPc	FD	GLO	EC
1	0.056951	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.073577	86.38926	0.051631	3.491250	9.525475	0.542380
3	0.088088	77.45650	0.972427	3.523457	17.66517	0.382449
4	0.101894	71.07261	1.762979	4.340547	22.53795	0.285915
5	0.111803	65.85499	3.448851	5.530281	24.89532	0.270556
6	0.119324	60.72404	7.269303	6.846076	24.91907	0.241512
7	0.126184	55.12905	13.31757	8.137160	23.18930	0.226927
8	0.133667	49.27206	20.80769	9.005188	20.69582	0.219235
9	0.142380	43.42886	28.65428	9.321383	18.38326	0.212212
10	0.151837	38.20090	35.80972	9.193649	16.58422	0.211504

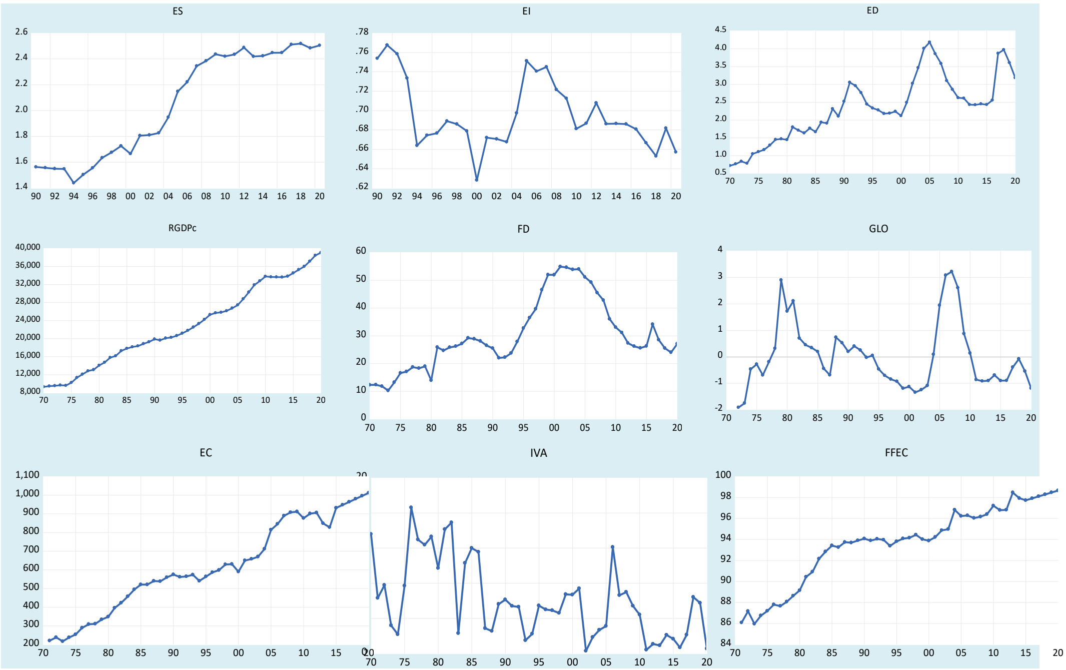
Table (E): Variance Decomposition of EI:

Period	S.E.	ES	RGDPc	FD	GLO	EC
1	0.021839	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.026384	83.50618	2.380952	0.722974	11.79898	1.590915
3	0.029434	70.50196	8.223969	0.583461	18.83736	1.853252
4	0.031157	67.25846	11.66115	0.987728	18.35797	1.734683
5	0.031653	66.26420	12.06132	2.029614	17.78809	1.856781
6	0.032092	64.55618	11.73630	2.840027	17.83580	3.031695
7	0.032654	62.84529	11.37372	3.322953	19.02015	3.437885
8	0.033272	61.14173	11.14876	3.608439	20.75780	3.343273
9	0.033885	59.98647	11.28378	3.694850	21.79724	3.237663
10	0.034347	59.49947	11.56778	3.651939	22.11481	3.166006

Table (F): Variance Decomposition of ED:

Period	S.E.	ES	RGDPc	FD	GLO	EC
1	0.285030	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.422506	98.45965	0.026869	0.701505	0.719484	0.092495
3	0.482510	93.72384	0.023813	2.888413	3.214701	0.149233
4	0.510568	86.47143	0.068059	6.463867	6.860412	0.136230
5	0.533135	79.30977	0.322318	10.01102	9.998241	0.358647
6	0.554817	73.90881	0.823258	12.46468	11.76107	1.042193
7	0.572977	70.13468	1.465515	13.84568	12.48708	2.067044
8	0.586597	67.41131	2.126283	14.57713	12.72925	3.156031
9	0.596587	65.37425	2.731479	14.98904	12.80736	4.097875
10	0.604179	63.81551	3.259829	15.25829	12.84871	4.817656

Figure (A): Study variables trends during the period, 1990 - 2020:



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