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Unpacking the Economic Environmental Nexus in Egypt: Insights from an ARDL Study on Determinants of GHG Emissions

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Abstract:The complex relationship between environmental aspects and economic functioning is one of the key challenges facing modern science. The greenhouse effect is intensified by the emissions of greenhouse gases, primarily produced by human activities (Anthropogenic activities). This study aims to investigate the relationship among the key economic determinants and GHG emissions in Egypt from 1990 to 2022. The GHG indicator used covers 7 types of gases. Variables of the study obtained from the official website of both Our world in data organization and World Bank; they are Greenhouse Gas (GHG) Emissions ($MtCO_2e$ -Metric tons of carbon dioxide equivalent), Population growth (annual %), GDP (growth, yearly %), Gross fixed capital formation for (private sector as % of GDP), Manufacturing, value added (% of GDP), Agricultural land (% of land area), and Transport services (% of service exports, BoP). The (ARDL) model, Autoregressive Distributed Lag, was used. Main results emphasize, that, population as well as agriculture have the strongest positive impacts. While GDP and manufacturing are secondary, but significant. Gross capital formation is the only variable reducing emissions, and transport services show no significant long-run effect. Based on the result, the study offers significant policy recommendations like controlling population growth, changing the energy policy, focusing on smart agriculture, and activating the role of green investment.

Keywords:- GHG – Economic - Environmental - determinants– population
JEL Codes: Q10 - Q18 - Q28 – Q29 - Q51

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1- Introduction:

At the level of the global economic system, economic instabilities have raised several questions about the extent of the ability of the free economy to regulate the international economic relations and transactions automatically, without the need to include new perspectives (Ze et al., 2023), such as the environmental and social perspectives, as the used method and tools were not able to routinely correct the imbalances that brought the global economy to the level of crisis (Han et al., 2023). There is no doubt that a general agreement at all levels in various countries about the need to link economic and environmental policies, but still, there is a large gap between the eloquence of speech and practical practices (Armali & Rahimian, 2024). The concerns were previously focused on the special effects of economic growth on the environment, and today there is a crucial need to understand how environmental degradation can lead to halting economic growth and even affect and change its direction and causing severe economic and social catastrophes at both local and international levels (Eissa, 2024). There is a complex relationship between environment and economy; such a relationship, if overlooked, leads to more environmental and economic problems. Environmental economists are still trying to understand this reciprocal relationship between both and comprehend effective solutions (Abbade, 2023).

The greenhouse effect is made stronger by greenhouse gases emissions (GHG) ([2]) mainly arises from anthropogenic activity, specifically economic actions, like using traditional fuels, example; coal or natural gas, in order to heat buildings and run factories or gasoline to power automobiles, agricultural activities, and land use produces greenhouse gases (Dolge & Blumberga, 2021). Carbon dioxide can also be released by trees and empty land, and a further source is landfills (Gamtessa, 2023). In cities, the main causes of emissions are electricity, industry, also waste disposal. The importance of the study of greenhouse gases arises from the economic and financial implications of global warming (Ghanbari & Daneshvar, 2020). This issue is unresolved from an economic and political perspective for several reasons, including the fact that benefits and costs are not equally allocated among nations, it is a long-term issue affecting generations, and it requires consideration of public and scientific opinion (Klakeel et al., 2023). One of the most significant greenhouse gases is carbon dioxide; 52% of this gas is emitted into the air as a result of economic and anthropogenic activity and can remain there for millennia (Rahman et al., 2023). The causes of greenhouse gas emissions vary depending on different factors, including:- the level and size of the economy, demographic distribution of population, the level of technology used in industry, agriculture, various services, and finally, the geographical nature of the country (Tudor & Sova, 2021). In general, most of these determinants are economic determinants that have a direct relationship with the economic activity in almost all countries.

From 137.79 (Mt) million tonnes of (CO2e) carbon dioxide equivalent in 1990 to 352 (Mt) of CO2e in 2022, total GHG emissions of Egypt's increased, accounting for 0.73% of global emissions (Eissa, 2024). The nation's GHG emissions rose by about 56% between 2005 and 2022, much higher than the global average of 24%. Land use and land-use change accounted for 4.3 (Mt) CO2e, or 0.1%, of Egypt's entire emissions

[2] Carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), , perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF_6), are the seven gases that make up greenhouse gas emissions index. (Gamtessa, 2023)

between 2002 and 2025 (Shaarawi et al., 2023).

The importance of this study arises from the fact that, in 2022, the carbon intensity of the Egyptian economy reached 884 grams CO2e per US dollar. This number is significantly higher than the global and EU averages (Eissa, 2023). With sustained GDP and population expansion, the Egyptian economy has seen a decoupling trend, pushed by fundamental economic reforms and improvements to the energy use of the industry (Shaarawi et al., 2023). As what cannot be measured cannot be managed, the study investigate the link between economic and environment in Egypt: through understanding the main determents of GHG emissions using ARDL model, so the decision-makers and society can be provided with indications emissions of GHG in the both short and long term, to estimate most important sources or determinants of these emissions so that our society can manage greenhouse gas emissions.

This study using data from (1990 -2022) about seven varibles Greenhouse Gas (GHG) Emissions (MtCO$_2$e -Metric tons of carbon dioxide equivalent), X1 Population growth (annual %), GDP (growth annual %), Gross fixed capital formation, (private sector % of GDP), Manufacturing, value added (% of GDP), Agricultural land (% of land area), and Transport services (% of service exports, BoP). Choosing variables done through literature review, testing the long run and short run relationships between variables using the ARDL Model, the main findings emphasize that population and agriculture have the strongest positive impacts. While GDP and manufacturing are secondary, but significant. Gross capital formation is the only variable reducing emissions, and transport services show no significant long-run effect. The current study provides an empirical endeavour to examine the economic environmental relationship in Egypt through understanding the key determinants of GHG emissions.

2- ***Importance of the study:***

- Absence of clarity in the link between specific economic determinants and GHG emissions when predicting or creating an economic or environmental decision.
- The importance of the current study about the main determinants of GHG emissions in Egypt is an emerging topic for further studies.
- Scarcity of empirical studies on the relationship between GHG emissions and their economic determinants in Egypt.
- There is a need to work on the macroeconomic level to measure and understand which economic activities affect GHG emissions to help policymakers.

3- ***Objectives of the study:***

- Understand the key economic drivers of GHG emissions & investigate the relationship between them.
- Explore the connection between GHG emissions and their key economic determinants in Egypt in both the short and long run.
- Discover the most appropriate model or methods and levels of integration among emissions of GHG and their key economic determinants in the Egyptian economy.
- Highlight reliable instruments to assess and mitigate the negative effects to help decision-makers.

4- Limitations of the study:

- This study purposes to investigate the relationship between the main economic determinants and GHG emissions in Egypt from 1990 – 2022

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5- Literature review:

5.1- Empirical literature.

In a study conducted by Abbade (2023) to calculate the global land footprint (LF) connected to food loss (FL) was calculated. He estimated GHG emissions from the burning of crop residues and the connection between that and global (FL) for the key crops. Results indicate that the global average (LF) linked to (FL) is approximately 69 (MH) million hectares annually, with maize, wheat, and rice accounting for the majority of this LF. The burning of crop leftovers in FL results in an average yearly emission of 48.8 kilotons of CH_4 and 1.26 kilotons of N_2O. When the three crops are taken into account, the emission of N_2O from FL crop residues is approximately 24.1 kilotons per year. High levels of food loss are associated with GHG emissions and LF, which emphasizes more for appropriate private and public measures globally to reduce LF and waste.

According to Armali & Rahimian (2024), the American public's opinion has not caught up with the consensus regarding climate change. A public climate change agreement gap is what this study proposes to investigate. The study quantifies the influence of growing public agreement on climate change on US greenhouse gas (GHG) emissions. The main findings are a strong correlation between increased public agreement and a subsequent decrease in greenhouse gas emissions. The study also calculates the impact of welfare connected to the agreement gap on change of climate among the public. Finding that by reducing this gap, the predicted reductions in GHG emissions can lead to welfare gains of up to $4.75 trillion. In another study by Eissa (2024) with the purpose of investigate the relationship between Egypt's cereal production between 1960 and 2022 and the effects of global warming and economic growth. Through using the Granger causality test and the (ARDL) model in this investigation. The key results of the study, while a short-term, negligible impact of global warming on cereal production, there is a long-term, significant, positive impact of global warming on both cereal production and GDP. This investigation advances the field of environmental economics through illuminating the relationship between food production, global warming, and the economy. Another study aims to find the main forces behind GHG intensity in Canadian industries by Gamtessa (2023). Given that Canada is considered a developed nation with high consumption of energy and greenhouse gas intensity, panel error correction, dynamic and OLS, fixed effects, methods were used in order to evaluate link between GHG intensity and its determinants. Besides the substantial intensity of energy, the results show that the fuel mix, the industrial production mix, which represents sectoral movements, and the time-fixed effects, which represent events like the implementation of technology standards and a carbon price, all had statistically significant effects on GHG intensity. Also, the study discovered that higher GHG intensity is associated with companies that depend more on fuel sources other than electricity.

The study of Ghanbari & Daneshvar (2020) used a comparative analysis between 1994 and 2014 to determine the share of total (GHG) greenhouse gas emissions from both rural and urban regions in 26 Middle East and Central Asian (MECA) nations, the dependent variable is total GHG emissions, independent eighteen variables were taken into consideration for the same purpose, including land area, CO2 emissions, energy use and consumption, population characteristics, GDP, etc. The statistical modeling built to examine greenhouse gas emissions included the quantitative methods of clustering analysis and correlation tests. One of the interesting findings is that in 2014, rural and urban sectors' emissions of GHG of all countries were equal to 74.5% of the entire emissions of GHG.

Golfam et al. (2024) did a study to forecast the demand for energy in the long term and evaluate such effect of employing renewable and sustainable energy technology on GHG emissions, to simulate the energy system in the years 2016–2040, demographic, macroeconomic, and per capita energy use data were collected and fed into the LEAP model at both agricultural and urban sectors. The main findings indicate that between 2016 and 2040, there will be an increase in the amount of electricity consumed and traditional fuels used by the urban and household sectors. In 2040, the study predicts that CO2 emissions will rise to 35.87 Mt, from 27.33 Mt in 2016. A prediction was developed in which rural areas currently disconnected from the national power grid would receive electrical service via residential solar panels (RSPs). According to the LEAP model, there would be a 17% decrease in CO2 emissions and a 20% substitution of solar-generated electricity for home diesel usage. Gogeri & Gouda (2024) studied GHG from the road transportation industry in India by creating and examining a list of fuel use over the last ten years, from 2011 to 2021. According to IPCC guidelines, Tier I & II which used in this study to estimate emissions. The (NCV) net calorific value of fuel used in a given country and its carbon content were used to produce the country-specific emission factor (EFCS), compared after being measured with (GWP) global warming potentials in the period of 2011-2021. According to estimates that depend on the country-specific factor of carbon emission, there were approximately 165.09 Mt in 2011 and 241.20 Mt in 2021. As a result, employing EFCS in 2021 has been shown to reduce CO2eq emissions by approximately 4.39%. Other gases, such as CH4 and N2O, have also shown similar declining tendencies. With a proposal to compare and account for greenhouse gas emissions from two sectors using panel data from 1997 to 2021, using a spatial econometric model for comparison analysis, Han et al. (2023) conducted their study. The main findings demonstrate that: (1) there was clear spatial variability and regional dependency in the overall volume and GHG intensity emissions from the two sectors, and the pattern of spatial distribution remained mostly steady. (2) There are significant differences in each factor's effect on the intensity of GHG and geographical properties of both sectors. The findings and the context of carbon max increase and carbon neutralization (dual-carbon) goals, all show the importance of this study, also its proposal for collaborative emission reduction strategies for the two sectors, respectively. Also, the study offers direction and a point of reference for the achievement of the dual goals of food security and GHG reduction from agriculture.

Landolsi & Miled (2024) conducted a study to locate the variables that have impacted variations in the amount of greenhouse gas emissions (GHG) associated with energy across time. The observed changes are examined about four factors: energy intensity, economic structure, economic activity, and pollution coefficient. This is done through the use of the additive and multiplicative LMDI decomposition approach. Results from Tunisia throughout the relevant period (2007–2017) indicate that rising GHG emissions are mostly caused by economic activity. They noted the program is positively but only slightly impacted by structural change. The observed increase in greenhouse gas emissions is largely attributable to the effect of increasing energy intensity.

In another study conducted by Le & Nguyen (2020) used panel data analysis to look at the factors that affected the global sample of 120 nations' emissions between 1995 and 2012. To be more precise, the EKC, in conjunction with an expanded STIRPAT model, was used to investigate the factors that influence the entire sample emissions and three subsamples of nations with varying levels of income. N2O, CH4, and CO2 emissions are three proxies for emissions that are utilized. The estimation approach used is (GMM) two-step generalized method of moments. The empirical findings indicate that there is proof of EKC for all country subgroups, as well as the global sample, about CO2 emissions. However, for CH4 and N2O emissions, U-shaped associations between emissions and income were observed for the three subsamples. For all country categories, energy intensity was the primary factor influencing CO2 discharges, and CH4 and N2O emissions for high income and upper middle income nations. Urbanization and industrialization consequences differed for various emission categories and income levels of nations. The purpose of a study conducted by Mahrous (2017) is to examine the primary economic factors that influence Ethiopia's emissions of greenhouse gases. The long- and short-term effects of industry, openness of trade, and economic growth on Ethiopian air pollution are assessed using the limits testing approach. The estimation process makes use of a data set that spans the years 1981–2013. Additionally, the study looks into whether or not the Ethiopian economy fits under the EKC concept. The results show that industry and trade liberalization together hurt Ethiopia's environment. Furthermore, there is currently no proof that EKC exists in Ethiopia.

The importance of a study conducted by Nasim & Nasim (2023) is that no analysis of Australia's state and territory levels for the factors influencing greenhouse gas emissions has been done before. In this study, the primary factors influencing Australia's growth in GHG are identified, and their effects are evaluated throughout the country's major states and territories. Using the Linear Panel, Data Model with random effects and (FGLS) Regression, Feasible Generalized Least Squares, the study conducts a statistical investigation and compares determinants' significance in the period 1990–2018 for 7 Australian states. The main findings are that certain states and territories indicate that a combination of GHG drivers is significant, while others indicate that none of the determinants are relevant. After examining environmental policies, the empirical results of this study are contrasted.

Ngarava et al. (2023) tried to find the connection between GHG emissions and AQUAP aquaculture production in Sub-Saharan Africa. The study employed an economic vector autoregressive (VAR) model to analyze yearly time series data about MP, GDP, GHG emissions, & AQUAP the period 1970-2020. The main results show that until 2006, when it unexpectedly surged, AQUAP in SSA was reduced. Within SSA, AQUAP has been controlled by Western & Central Africa. Up until 1991, there was a periodic decline in GHG emissions. After that, they started to climb gradually. While AQUAP impact GHG by an unbalanced way regarding emissions, GHG emissions had a negative long-term and short-term impact on AQUAP. GDP is favorably impacted by AQUAP in both the short and long terms, and GDP was asymmetrically affected by GHG emissions. Furthermore, AQUAP lowered short-term greenhouse gas emissions while raising them over time. This represents the early stages of (EKC) and the sector's infancy in SSA.

Rahman et al. (2023) tried to investigate the effects of the growth of population, economic expansion, and the consumption of different sources of energy on GHG emissions of the chosen South Asian economy. Utilizing the model STIRPAT. Results are estimated for the years 1972–2021 using slope of homogeneity (SH), dependence of cross-sectional (CSD), and cointegration tests, with second generation unit root testing. The (CS-ARDL) cross-sectional auto-regressive distributive lag model is used to estimate the values of chosen variables due to the existence of mixed-order unit root issues, CSD, and SH. Main findings indicate that while population and GDP have a favorable but negligible short-term impact on nations of South Asian, GDP has a considerable long-term impact. Additionally, the study displayed that fossil fuels burning raises atmospheric emissions of gases considerably. Nuclear and renewable sources of energy also contribute significantly and constructively to the reduction of pollution in South Asian nations. Therefore, to fully reap the benefits of increased production of safe and environmentally friendly energy.

The effects of Egypt's growing NGV fleet on the economy and environment, taking into account potential future scenarios, have been studied by Shaarawi et al. (2023). It also intends to examine the government's strategy, which focuses on expanding the infrastructure of CNG fuelling stations and offering incentives for NGV transition. Results From the beginning to the end of 2021, Egypt's NGV program resulted in savings of around US$1.4 billion, or 21.57 billion EGP, and a reduction of approximately 5 Mt CO2 emissions. Additionally, the government's push to accelerate NGV adoption in 2021 resulted in a significant reduction in CO2 emissions and economic savings of almost 40% and 49%, respectively, over the previous year. According to scenario no. 1, which calls for an NGV to adopt a 15% increase. This scenario is expected to result in an approximate 30 Mt CO2 reduction in emissions and an approximate US$17.6 billion, or 278 billion EGP, in economic savings. Tudor & Sova (2021) conducted a study with the goal of finding more precise greenhouse gas (GHG) emission estimates. Using data from 1970 to 2018 and six machine learning and econometric models, the study projected the GHG route of emissions in twelve of the most polluting countries. The (NNAR) Neural Network Autoregression model consistently shows the greatest forecasting out-of-sample performance for emissions of GHG at various forecasting prospects, the findings show that the twelve most polluting countries in the world are expected to have an average increase in total GHG emissions of 3.67% between 2021 and 2030, according to predictions produced by the NNAR model. Also, the findings consequently emphasize the need for more effective policies and initiatives to help achieve the goals. Vera et al. (2023) investigated the fact that Natural gas and electricity are becoming more and more dependent on one another. Does this fact align with reducing carbon emissions from the electricity industry? Through a analysis and decomposition of electricity-related (GHG) emissions in Mexico in the period 1990 - 2015, they investigated this subject. To measure the differences in electricity GHG emissions associated with activity, carbon coefficient, structure, and energy intensity impacts, the study used (LMDI) the Logarithmic Mean Divisia index. The structural and intensity of energy effects helped to restrain the GHG emissions growth, but the activity consequence was the main driver of that expansion. The effect of carbon coefficient had a negligible impact on GHG emission mitigation.

Another study by Xiao et al. (2024) investigates the characteristics of the distribution and factors behind GHG emissions from domestic and urban treatment of wastewater across regions and in different years. This has been done by using LMDI decomposition method and Kaya model to examine changes in emissions of GHG at the provincial level for urban treatment of wastewater. Main findings show that urban residential wastewater treatment greenhouse gas emissions are rising over time. Based on the driving factors' decomposition results, economic size emerges as the primary positive driver, with minimal positive contributions from the population effect. The primary cause of the problem is the sludge disposal structure; negative contributions have been limited by technology. Based on the decomposition results, Guangdong and Shandong, two of the largest coastal GHG polluters, need to invest in technology and capital to continually develop wastewater treatment processes and reduce non CO2 emissions.

In order to reduce greenhouse gas emissions from agricultural systems, Yi et al. (2024) studied and estimated China's GHG emissions from agriculture. GHG emissions at the provincial and regional levels are quantitatively calculated using the emission factor approach and the CLUMondo model. Furthermore, the three-dimensional distribution, carbon source structure, and types of agricultural GHG emissions at different phases were qualitatively analyzed. Main findings showed; under a natural development scenario, the three-dimensional of agricultural distribution of land in 2035 will largely match that in 2020. In general, greenhouse gas emissions from agriculture will keep rising. The simulation results indicated that agricultural GHG emissions persisted at high levels in the east, south, southwest, and central China and that an agglomeration of high-emitting provinces progressively evolved in the southwest and northeast of China. Also, a Study conducted by Ze et al. (2023) focuses on SDG 13 (Climate Change) and also looks at how China's economic growth, employ of its natural resources, development of the financial sector, openness, and GHG emissions relate to each other to attain sustainable development. The study used OLS, FMOLS, and DOLS econometric methodologies on data of time series spanning the period 1990-2021. The study's main findings are that China's emissions of GHG and income growth per capita have an inverse relationship (U-shaped). On GHG emissions, the beneficial use of natural resources and the detrimental effect of financial development were also noted. Furthermore, it was discovered that international commerce internationally reduced greenhouse gas emissions. To achieve the SDGs, the report recommends fostering greener technology, economic development, and resource efficiency, as well as trade openness that takes the environment into account. Even if SDGs 1, 2, 4, 6, and 11 have been achieved, SDG 13 still needs to be achieved by addressing the issues of green growth, resource efficiency, and greenhouse gas emissions.

5.2 - Theoretical and Policy Literature.

Ali et al. (2024) used a bibliometric analysis to perform a trend study to look at the gaps in knowledge in research on comprehending the elements that determine environmental deterioration. To accomplish this, they searched the Dimensions database for relevant keywords and retrieved published scientific articles from 2000 to 2023 for review. According to the report, the primary emphasis of degradation of environment has changed over period of time. From 2000 to 2005, it was only the ecological footprint; however, from 2013 to 2023, it also included other factors, like GHG, carbon footprint, carbon sequestration, input-output analysis, and renewable energy. Additionally, academic publications on environmental degradation have increased dramatically over the past ten years. The findings also showed that indoor air pollution is linked to the development of environmental deterioration. As a result, studies must concentrate on interior air pollution since it may have a more severe and immediate effect on environment also human health. Assesses degree to which the Green Deal targets have been implemented and examines the primary factors influencing variations in GHG emissions within the European Union.

Dolge & Blumberga (2021) conducted a study to analyze the EU twenty-eight countries, which include UK, throughout a 10 year study period, 2010 - 2019. According to findings, energy efficiency upgrades in the EU have twice as much of an effect on lowering GHG emissions from using renewable energy sources. Primary countervailing factor impeding the achievement of greater decreases in GHG emissions was the impact of economic expansion. Previous and next research is conducted in greater detail for the Baltic States. Three distinct development scenarios, including the one with the current methods, the one with new methods, and the scenario with as usual condition, are used to predict GHG emissions using a novel forecasting technique. The findings also indicate that stronger steps have been taken to compel climate moderation methods in the economy, as the Baltic States' present policies for climate are insufficient toward meet the 2030 targets of emission reduction . A literature survey was conducted by Klakeel et al. (2023). A variety of relevant articles published between 2018 and 2022 were reviewed for the poll. The main drive behind this study was to determine the actual amount of literature that is currently accessible on diverse technologies and, more analytically, to serve as a policymaking backing tool for quantitatively picking a technology underneath particular conditions. The technologies were separated into four categories: fuel cell, renewable energy, low-carbon or alternative fuels, and fossil fuel-based technologies. Also, the findings of this study will be useful in identifying specific research gaps when evaluating the relative effectiveness of different GHG emission reduction solutions. The ultimate goal is to create a thorough plan that can be applied to lower GHG emissions.

Li et al. (2024) calculate China's four-stage greenhouse gas emissions from food. For all food categories, the study found that the stages of manufacturing besides processing are more GHG emissions than from other stages of marketing and transportation. Because of their differing eating practices, three-fifths of the provinces emit more greenhouse gases from vegetarian meals than animal-based meals. Through a comparative analysis of various dietary guidelines, the study has developed (LDG) Low-carbon Health Dietary Guideline, which puts into interpretation both dietary aspects and reduction of emissions aims. The nutrition is customized in order to account for variations of age, gender, race, also income. The main findings, that China's food-related greenhouse gas emissions in 2050 will be (167 Mt CO_2-eq) with considering the LDG diet, which is 19% lower compared to under (BAU) business as usual scenario, and 34% lower than under the Chinese Dietary Guidelines (CDG).

Pottier & Treut (2023) discuss sustainable work, the carbon impact of financial portfolios and investments, and the emissions made possible by supplying inputs to manufacturing processes. By means of the multi-regional input-output database, the researchers calculate downstream intensity of carbon for key inputs from 35 French industries. Presenting a comprehensive overview of enabled emissions, breaking down emissions by major input and industry. Because of the extreme variation in carbon intensity between industries, emissions based on income are distributed far more unequally than wages.

In another related study conducted by Ćetković et al. (2021) present the financial and economic evaluation of Montenegro's GHG emission reduction initiatives. Cost-effectiveness, cost-benefit, and least-cost analyses were carried out in this regard. The analysis's findings showed that Montenegro's energy sector is predicted to have the biggest drop in GHG emissions over the next ten years because of the thermal power plant restoration, more use of sources from renewable energy, and initiatives regarding energy efficiency.

Table: (1) Summary of Man Literature

#	Author	Main variables	Countries	Model used
1	**(Abbade, 2023)**	**Greenhouse gas emissions, Land footprint, and 4 Crops data**	**Apply worldwide**	**Ordinary Least Squares Estimation (OLS)**
2	**(Eissa, 2024)**	**Mean temperatures, GDP per capita (growth annual%), and cereal production (Mt)**	**Egypt**	**(ARDL) model**
3	**(Gamtessa, 2023)**	**Greenhouse gas emissions, energy intensity fuel mix, and industrial production mix**	**Canada**	**panel error correction, dynamic fixed effects, and dynamic OLS methods**
4	**(Ghanbari & Daneshvar, 2020)**	**GHG emissions, population characteristics, land area, energy use energy consumption, CO2 emissions. And GDP.**	**Panel data 26 (MECA) nations**	**Quantitative methods of clustering analysis and correlation test**
5	**(Golfam et al., 2024)**	**GHG emissions, renewable energy technology, electricity consumed, and fossil fuels**	**Iran**	**The LEAP model**
6	**(Landolsi & Miled, 2024)**	**GHG emissions, energy intensity, economic structure, economic activity, and pollution**	**Tunisia**	**additive and multiplicative LMDI decomposition**
7	**(Mahrous, 2017)**	**GHG emissions, industry, trade openness, and economic growth**	**Ethiopia**	**The limits testing approach**
8	**(Rahman et al., 2023)**	**GHG emissions, population growth, economic expansion, and the use of different energy sources**	**chosen South Asian economy**	**ARDL model & model STIRPAT**
9	**(Tudor & Sova, 2021)**	**GHG emissions trends from 1970 to 2018 and 6 econometric and machine learning methods.**	**12 of the most polluting economies**	**(NNAR)The neural network autoregression model**
10	**(Ze et al., 2023)**	**Economic growth, Natural resources use, trade openness, financial development, and greenhouse gas emissions.**	**China**	**OLS, DOLS, and FMOLS.**

6- *Methodology:*

6.1 Hypotheses:

1. (H0) - There is no correlation between Greenhouse Gas (GHG) Emissions ($MtCO_2e$) and the other six variables used in the study, in long and short run.
2. (H1) - There is a correlation between (GHG) Emissions ($MtCO_2e$) and Population growth (annual %), in long and short run.
3. (H2) - There is a correlation between (GHG) Emissions ($MtCO_2e$) and GDP growth (annual %), in both and short run.
4. (H3)There is a correlation between (GHG) Emissions ($MtCO_2e$) and Gross fixed capital formation, (private sector % of GDP), in long and short run.

5. (H4) - There is a correlation between (GHG) Emissions ($MtCO_2e$), and Manufacturing, value added (% of GDP), in long and short run.
6. (H5) - There is a correlation between (GHG) Emissions ($MtCO_2e$) and Agricultural land (% of land area), in long and short run.
7. (H6) - There is a correlation between (GHG) Emissions ($MtCO_2e$), and Transport services (% of service exports, BoP), in long and short run.

6.2 Variables:

Table: (2) Variables and data

#	Variable	Symbol	Unit of measurement	source	Used in literature
1	**Greenhouse Gas (GHG) Emissions (Y)**	**GHG**	**($MtCO_2e$ - Metric tons of carbon dioxide equivalent)**	**Our world in data organization ***	**+ & -**
2	**Population growth (X1)**	**POP**	**(Annual% Increase)**	**World Bank**	**+**
3	**GDP growth (X2)**	**GDP**	**(Annual% increase)**	**World Bank**	**+&-**
4	**Gross fixed capital formation, private sector (X3)**	**GFC**	**(% of GDP)**	**World Bank**	**-**
5	**Manufacturing, value added (X4)**	**MNF**	**(% of GDP)**	**World Bank**	**+**
6	**Agricultural land (X5)**	**AGR**	**(% of land area)**	**World Bank**	**+ & -**
7	**Transport services (X6)**	**TRN**	**(% of service exports, BoP).**	**World Bank**	**+**

*** https://ourworldindata.org/greenhouse-gas-emissions**

7- The Data and Model

According to the applied literature discussed in the first section, the estimated model links the Greenhouse Gas Emissions (GHG) as the dependent variable, and other 6 determinants affecting this rate as independent variables. Proposed model used is as follows:

GHG=f(POPt, GDPt, GFCt, MAFt, AGRt, TRNt). (1)

Thus, the equation of the proposed model can be written as follows:

GHGt = $\boldsymbol{\beta}$0+ $\boldsymbol{\beta}$1 POPt +$\boldsymbol{\beta}$2 GDPt + $\boldsymbol{\beta}$3 GFCt+ $\boldsymbol{\beta}$4 MAFt+ $\boldsymbol{\beta}$5 AGRt + $\boldsymbol{\beta}$6 TRP0t + ut (2)

The research used time series for all variables for the period (1990-2022) from the Our World in Data organization, and World Development Indicators issued by the World Bank for Reconstruction and Development.

A standard model that illustrates the impact of economic determinants on the rate of (GHG) emissions in Egypt: This model aims at estimate the parameters of the factors affecting (GHG), identify their impact, in addition to determine the relative importance of each of them during the period (1990-2022). To find out the impact of the main determents on GHG emissions in Egypt, the (Bounds Test) method, known as "ARDL" (Auto Regressive Distributed lag) was used based on the Error Correction Model "ECM"), which contains the presence of time lags, from which relationships can be measured in the long and short term. This method of analysis is distinguished from others by the following:-

- ✓ It is used in the case of a difference in the degree of integration between the variables in the model I (0) or I (1).
- ✓ It is used in the case of small samples because it is accurate.
- ✓ Taking into account structural changes in the time series of variables over time.

8- Results

Table: (3) Statistics descriptive:-

Variable	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Obser.
GHG	244.64	244.48	66.17	137.79	337.92	0.08	-0.82	32
POP	2.07	2.06	0.25	1.57	2.56	-0.36	-0.85	32
GDP	4.31	4.35	1.64	1.13	7.16	-0.14	-0.68	32
GFC	8.25	8.06	2.76	3.74	14.41	0.45	-0.63	32
MNF	16.40	16.34	0.65	15.37	18.50	0.87	1.16	32
AGR	3.52	3.54	0.33	2.66	4.10	-0.75	0.12	32
TRN	36.60	36.34	8.13	26.98	60.20	0.63	-0.32	32

Source: Calculations based on Data from 1990-2022 using Stata.

For (GHG), mean 244.64 and median 244.48, this means a homogeneous distribution, with no extreme skew, and the range (137.79/337.92): Emissions nearly doubled from 1990 to peak in 2017. For (POP), mean (2.07%) and median (2.06%), this means stable central tendency, but a declining trend (Max = 2.56% in 1990 to Min = 1.57% in 2022). For (GDP), mean (4.31%) and median (4.35%), this means balanced distribution, but high instability as (Std. Dev. = 1.64). For (GFC), mean (8.25%) and median (8.06%), this means slight right skew, influenced by high values (14.41% in 2008).

Table: (4) Pearson correlation matrix

Variable	GHG	POP	GDP	GFC	MNF	AGR	TRN
GHG	1.00						
POP	-0.82***	1.00					
GDP	0.45**	-0.31*	1.00				
GFC	-0.67***	0.53***	-0.37**	1.00			
MNF	0.12	-0.41**	0.09	-0.57***	1.00		
AGR	0.32*	-0.63***	0.21	-0.48***	0.39**	1.00	
TRN	-0.25	0.18	-0.33*	0.42**	-0.23	-0.51***	1.00

***p < 0.01, **p < 0.05, p < 0.1
Source: Calculations based on Data from 1990-2022 using Stata.

GHG (Y) and POP (X1) were slow (declining X1), GHG (Y) increased where r = -0.82 (Strong negative correlation). GHG (Y) and GFC (X3) Higher Gross fixed capital relates to lower emissions, where r = -0.67 (Strong negative correlation). POP (X1) and AGR (X5) declining population growth aligns with reduced agricultural land use, where r = -0.63 (Negative correlation).
GHG (Y) and GDP (X2) Economic growth drives emissions, supporting the Kuznets hypothesis. Where r = 0.45 (Positive correlation). GFC (X3) and MAF (X4), higher capital formation may drive economies away from manufacturing, where r = -0.57 (Negative correlation). TRN (X6) and AGR (X5) with less agricultural land, may Egypt rely more on transport-intensive trade, where r = -0.51 (Negative correlation). GHG (Y) and MAF (X4), where r = 0.12 (No clear link), also GHG (Y) and TRN (X6), where r = -0.25 (Borderline).

Table: (5) Unit Root Tests (ADF)

Variable	ADF Statistic	p-value	Order of Integration
GHG(Y)	-2.45	0.13	I(1)
POP(X1)	-1.89	0.34	I(1)
GDP(X2)	-3.12*	0.03	I(0)
GFC(X3)	-2.78	0.06	I(1)
MAF(X4)	-3.45**	0.01	I(0)
AGR(X5)	-2.91*	0.04	I(0)
TRN(X6)	-2.67	0.08	I(1)

* $p < 0.05$ (reject null at 5%) & ** $p < 0.01$ (reject null at 1%)
Source: Calculation based on Data from 1990-2022 using Stata.

Through conducting the unit root test, the researcher found that there is no stationarity, and so the model is valid at level I(0) & the first difference I(1). Therefore, the researcher concludes that the variables have stability in long run as well as in short run. Based on results of the ADF test, the researcher can reject, null hypothesis and conclude; the time series is stationary. The dataset has a mix of I(0) and I(1) variables, no I(2), making (ARDL) Model suitable for the cointegration analysis.

Table: (6) Lag Selection
Optimal lag selection based on AIC:

Lag	AIC
1	3.45
2	3.32*
3	3.38

Selected ARDL (2,2) model

Table: (7) Bounds Test Results: The F-test for cointegration yields:

Test statistic	Value
F-statistic	5.87**
1% Critical value (I(0))	3.74
1% Critical value (I(1))	5.06
5% Critical value (I(0))	2.86
5% Critical value (I(1))	4.01

Source: Calculations based on Data from 1990-2022 using Stata

The calculated F-statistic (5.87) on this value exceeded the upper critical bound exceeded at both 1% (5.06) and 5% (4.01) significance levels. This provides strong evidence for cointegration, indicating that a stable relationship in long run exists among GHG emissions and 6 explanatory variables. Bounds test approves that GHG emissions maintain a balanced relationship with the research variables: POP(X1), GDP(X2), GFC(X3), MAF(X4), AGR (X5), and TRN (X6). This suggests that any interventions or changes affecting any of these variables would have long-term impacts on GHG emissions.

Table: (8) Long-Run Coefficients estimation

Variable	Coefficient	Std. Error	t-statistic
POP (X1)	12.45***	3.21	3.88
GDP (X2)	3.67**	1.45	2.53
GFC (X3)	-1.89*	0.97	-1.95
MAF(X4)	2.34**	0.89	2.63
AGR (X5)	5.12***	1.23	4.16
TRN (X6)	-0.67	0.72	-0.93

*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: Calculations based on Data from 1990-2022 using Stata

We notes from the table (8) that POP(X1) has the strongest positive impact on GHG, GDP(X2) shows a significant positive relationship to GHG, GFC (X3) has a negative coefficient (possibly more enhancement), and AGR (X5) shows a strong positive relationship to GHG.

Table: (9) Error Correction Model (ECM)

Variable	Coefficient
ECM(-1)	-0.45***
Δ POP (X1)	8.23**
ΔGDP (X2)	2.11*
ΔGFC (X3)	-1.02
Δ MAF(X4)	1.45*
ΔAGR (X5)	3.67***

The error correction term ECM(-1) is -0.45 and highly significant, indicating about 45% of disequilibrium is corrected each year.

Table: (10) Test Results for Granger Causality

Null Hypothesis (H_0)	F-Statistic	p-value	Conclusion (5% sig.)
X1 (POP) does not Granger-cause Y(GHG)	4.32	0.023	Reject H_0 (Causal)
Y(GHG) does not Granger-cause X1 (POP)	1.56	0.227	No causality
X2 (GDP) does not Granger-cause Y(GHG)	3.89	0.031	Reject H_0 (Causal)
Y (GHG) does not Granger-cause X2(GDP)	0.98	0.387	No causality
X3 (GFC) does not Granger-cause Y(GHG)	2.45	0.102	No causality
Y (GHG) does not Granger-cause X3(GFC)	5.12	0.012	Reject H_0 (Reverse Causal)
X4 (MAF) does not Granger-cause Y(GHG)	3.21	0.049	Reject H_0 (Causal)
Y(GHG) does not Granger-cause X4(MAF)	1.23	0.305	No causality
X5 (AGR) does not Granger-cause Y(GHG)	6.78	0.003	Reject H_0 (Causal)
Y (GHG) does not Granger-cause X5(AGR)	0.87	0.428	No causality
X6 (TRN) does not Granger-cause Y(GHG)	1.98	0.154	No causality
Y(GHG) does not Granger-cause X6(TRN)	3.45	0.042	Reject H_0 (Reverse Causal)

Source: Calculations based on Data from 1990-2022 using Stata

POP (X1) and GHG (Y) as increasing population leads to higher consumption of energy and emissions. GDP (X2) and GHG (Y) economic expansion drive industrial activity and fossil fuel consumption. MAF (X4) and GHG (Y) Industrial production is a main source of CO_2 emissions. AGR (X5) and GHG (Y), changing like land use, contribute to methane and CO_2 emissions.

GHG (Y) and GFC (X3) higher emissions may lead to green investment changes. GHG (Y) and TRN (X6) emission regulations may adjust the transport sector.

GFC (X3) does not directly cause GHG (but the reverse does), also TRN (X6) does not directly cause emissions (but the reverse does).

8.2 Summary of the results in the long run

1. Significant /positive determination, as, 1% increase in annual POP growth leads to a 12.45 $MtCO_2e$ rise in long-run GHG emissions. Which confirms the correctness of the first hypothesis (H1).
2. Significant /positive determination as a 1% rise in GDP growth increases GHG by 3.67 $MtCO_2e$, confirming the growth-emissions link (Kuznets hypothesis). Which confirms the correctness of the second hypothesis (H2)
3. Significant /positive determination as 1% growth of AGR raises GHG emissions by 5.12 $MtCO_2e$, likely due to methane (livestock) and agricultural operations impacts. Which confirms the correctness of the fifth hypothesis (H5).
4. Significant /positive determination as a 1% increase in MAF share adds 2.34 $MtCO_2e$, reflecting industrial energy use. Which confirms the correctness of the fourth hypothesis (H4)
5. Non-significant /Negative determination as a 1% rise in private investment reduces emissions by 1.89 $MtCO_2e$, suggesting due to clean tech adoption. Which confirms the correctness of the third hypothesis (H3).
6. TRN is insignificant, but the negative sign hints at potential efficiency improvements (likewise, the GFC).

8.3 Summary of the results in the short run

1. 1% increase in POP raises GHG by 8.23 $MtCO_2e$ in the short term. Stronger than long-run effects, suggesting an immediate energy/resource demand increase. Which confirms the correctness of the first hypothesis (H1)
2. 1% rise in AGR increases GHG by 3.67 $MtCO_2e$. Reflects methane (livestock) and agricultural operations impacts. Which confirms the correctness of the fifth hypothesis (H5).
3. Short-term GDP has a smaller but significant positive effect on GHG, aligning with short-term business cycle-linked emissions. Which confirms the correctness of the second hypothesis (H2).
4. MAF contributes to GHG, but less than population & agriculture. Which confirms the correctness of the fourth hypothesis (H4)
5. GFC, coefficient = (-1.02) is insignificant ($p > 0.1$). Suggests the absence of short-term GHG impact from the GFC. Which proves the third hypothesis wrong (H3).

9- Conclusions and discussions:

Referring to the study hypotheses, we find that the six hypotheses confirm the existence of a correlation between GHG and each of the population growth, gross domestic product, gross capital formation, added value from industry, agricultural land area, and transportation services. This is what the results of the statistical study confirmed, and by analyzing these results, it was found that:

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- The long-run statistics reveal how each explanatory variable influences GHG emissions in a continuous and balanced association.
- The top emission determinants in the long run are: Population (POP) and agriculture (AGR) have the strongest positive impacts. GDP and manufacturing (MAF) are secondary but significant. Gross capital Formation (GFC) is the only variable

reducing emissions, underscoring its policy importance. Transport services (TRN) show no significant long-run effect.

- In short run, error correction is -0.45 and highly significant, indicating that about 45% of disequilibrium can be corrected every year. So the system in Egypt is responsive to shocks moderately, taking 2.2 to 3 years to fully correct any defects, meaning if there is a 100% increase in GHG, the system can reduce 45% of such an increase every year if at hand an appropriate policies.
- As for the link between population & GHG emissions, it is significant & positive, both in the short and long run increase in population with no doubt will increase consumption goods and services and consequently increase the GHG emissions. (Xiao et al., 2024). Egypt's population in 2024 is expected to be approximately 107,205,000, compared to 109.3 million in 2020, with a growth rate of 2.2% annually (Eissa, 2024).
- The relation between GDP & emissions of GHG is significant & positive in the long and short run; however, the effect is small in the short run. As in Egypt GDP affect by many international and local economic factors which is lead to slowing down economic growth, such a situation will affect the relation between GDP & GHG emissions in short run also such results matching results of some Literature like the study of (Dolge and Blumberga., 2021; Eissa, 2023b; Gamtessa, 2023; Le and Nguyen., 2020; Mahrous, 2017; Rahman et al., 2023; Ze et al., 2023)
- For the relation between Gross Capital formation GFC and GHG, the relationship is insignificant both in short run and long run. In general, gross fixed capital formation has a complicated connection with pollution and emissions, having both positive and negative consequences (Gogeri & Gouda, 2024). Which represents investments in fixed assets, such as machinery and infrastructure, can stimulate economic growth while potentially increasing resource consumption and emissions. From the other side, it can enable the adoption and creation of cleaner technologies, more efficient production, thereby reducing pollution (Han et al., 2023). In the case of Egypt and since 2005, the government has started using the new investment strategy to reduce pollution and emissions (Shaarawi et al., 2023).
- For the relationship between MAF or Manufacturing, value added and GHG emissions it is significant and positive it means that more manufacturing activities means more GHG, it is a fact that higher production levels frequently result in higher energy consumption and industrial operations that emit pollutants into the atmosphere, water, and soil, affecting ecosystems and human health (Klakeel et al., 2023). In Egypt, Manufacturing, particularly linked with higher value added, has a substantial impact on pollution (Shaarawi et al., 2023).
- For the relationship between agricultural activities represented as land use AGR and GHG emissions, the research found a significant and positive relationship in both the long and short term. Egypt's agricultural industry is facing tremendous problems due to pollution and climate change, which are affecting food production and security (Eissa, 2024). Intensive agricultural practices, such as the use of fertilizers and pesticides, add to water and soil pollution, while climate change worsens water scarcity and extreme weather events, jeopardizing crop production and food security (Abbade, 2023).

For the relation between the services of transportation TRN and emissions of GHG, the relationship is insignificant and negative, but the negative sign gives suggestions for possible efficiency improvements, like logistics optimization. In Egypt, transportation services contribute significantly to air pollution, particularly in metropolitan areas. Road transportation, particularly older automobiles, is a significant source of PM2.5 and other pollutants (Eissa, 2024). While the government is investing in greener transportation choices such as electric buses and natural gas automobiles, there are still concerns about fuel quality and the need for greater modal changes to public transportation (Shaarawi et al., 2023b).

Through the current study, which addressed a small part of the relationship between the economy and the environment, we confirmed the traditional conclusion that supports environmental degradation as a result of economic activities and the existence of a deep relationship between the economy and the environment. The link between the economy and the environment has always been a major concern of economists during the past century and has become a reality confirmed by modern research.

10- Policy recommendation:

Controlling population growth by activating family planning programs, supporting small families, paying attention to reproductive health, and linking family planning programs to economic incentives.

An energy policy that seeks to establish a low-carbon energy system must take into attention the combination of "Fossil fuel, renewable energies, and energy efficiency" energy mix.

Focusing on smart agriculture, activating and utilizing modern agricultural systems such as artificial intelligence, and developing and supporting agricultural projects that rely on energy conservation and efficient production.

Spreading environmental awareness and education among all societal parties, especially civil society organizations, and activating the role of these parties in preserving the environment, through participation in creating and developing more indicators of Egyptian sustainable development.

Activating the role of green investment and encouraging investors to direct their financial capabilities to this field, for example, investing in clean energy and hydrogen energy as an alternative to traditional energy.

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