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# CONSIDERATION OF THE IMPACT OF THE TRANSITION FROM A CASH CROP ECONOMY ON THE CARBON FOOTPRINT

*The object of the study is the carbon footprint ($CO_2$), which is skyrocketing despite augmented awareness of this issue and a growing willingness to act. The effects of climate change have recently become more severe and have garnered international attention. Recent discussion has focused on carbon footprint as one of the most urgent global issues facing all nations. The tradeoff between carbon footprint and economic growth for credible climate change measures is still understudied in terms of rigorous economic causal analysis. To comprehend the magnitude and speed of the transition away from an agricultural-based economy, it is necessary to quantify and compare the levels of carbon footprint associated with the agricultural, industrial, and service sectors of the country. In order to understand each economic sector's individual contributions to the overall carbon footprint and to assess the relationship between level of economic diversification and the levels of emissions, first identify the main factors and forces that have an impact on each sector's carbon footprint and then consider how the country's transition away from an agricultural-based economy has affected emissions in other economic sectors. This study investigates the impact of the economy's transition away from cash crops on carbon footprint, analyzes the conversion-affecting variables, and quantifies the significance applying the environmental Kuznets curve (EKC), and then regress the model. It is found that there is an inverted U-shaped pattern in the association between carbon footprint and each of industry, service, and manufacturing value added; agriculture, however, shows insignificant inverted U-shaped pattern. In addition, we discovered that every dependent variable – aside from the GDP contribution of agriculture – has a positive correlation with carbon footprint. Analysis revealed that improving agriculture results in lower carbon dioxide emissions. While the economic contributions of agriculture are more environmentally friendly, those of industry, services, and manufacturing leave carbon footprints behind to achieve sustainability, agricultural policy subsidies and deregulation may function as driving factors for the expansion of the cash crop economy. On the one hand, tax policy may be an effective instrument for boosting low-carbon energy consumption in the sector. It is presumptive that environmental phenomena, such as earthquakes, tsunamis, and flues, have not had a significant impact on the economy. This article is pertinent to the nations now dealing with significant environmental problems.*

***Keywords:*** *Bangladesh, carbon footprint, environmental Kuznets curve, foreign direct investment, economic growth, gross value added.*

## 1. Introduction

Carbon footprint displacement has slower spillover effect [1, 2]. Environmental issues are among the most critical problems and the threat of climate change brought on by growing global warming has been a significant environmental problem over the past thirty years. The creation of greenhouse gases (GHG), the majority of which are carbon dioxide (carbon footprint), is the primary factor causing climate change [3]. According to the US EPA's 2017 report, carbon footprint, methane, $NO_2$, and fluorinated gases account for 79 %, 11 %, 7 %, and 3 % of all greenhouse gases [4]. In the 5th IPCC Review Article, the international community decided that global temperatures should not rise beyond 2 °C by the twenty-first century's end [5].

The majority of nations committed to combating environmental pollution by establishing nationally determined contributions by signing the Paris Agreement. Countries are encouraged to reprioritize their sustainable economic drive by promoting the economic policies explained by the environmental Kuznets curve (EKC) hypothesis. EKC claims that there is an inverse U-shaped relationship between income and environmental deterioration [6]. Initially, income increases in response to environmental degradation increases until a turning point is attained, and then the environmental condition is expected to revive. Previous studies in-depth examined EKC relationship and tested the validity of it using various indicators. A few earlier studies looked at the applicability of EKC for Bangladesh, but their findings were different on the basis of indicators. While the

current study aims to use the value-added components of the economy, the aforementioned studies all examined the relationship among income, environmental quality and the aggregate level of gross domestic product (GDP) and some other interconnected variables. *The aim of research* is to examine EKC at fragmented GDP levels in terms of gross value added in manufacturing, services, industries, and agriculture. Bangladesh is expected to lose around four percent of its GDP annually because of environmental concerns [7], making it one of the nation's most susceptible to climatic change as a result of global warming. In the last 20 years, combustion of fossil fuels was responsible for about 75 % of the carbon footprint that was caused by humans. Fossil fuels, on the other hand, are the main source of electricity, manufacturing, transportation, and consumer spending, all of which are closely related to economic expansion.

There is growing concern about the potential impact of this economic transformation on carbon footprint as countries move away from a cash crop economy and toward industrialization and service-oriented sectors. This paper looks into how the shift from an agricultural economy to other sectors may affect carbon footprint. The study seeks to shed light on the environmental effects of economic diversification and the requirement for sustainable development policies by examining the potential ramifications of this shift.

To quantify and compare the levels of carbon footprint associated with the agricultural, industrial, and service sectors over the 32 years period between 1990 and 2020 in Bangladesh in order to understand the extent and swiftness of the shift away from an agricultural-based economy. After that, determine the primary forces and variables that affect the carbon footprint within each economic sector to comprehend their individual contributions to the overall carbon footprint and evaluate the relationship between Bangladesh's degree of economic diversification and the levels of emissions. Finally, consider how policy changes and regulatory actions have affected emissions in various economic sectors as the country moves away from an agricultural-based economy.

This article intends to demonstrate how a nation's economic transition affects its carbon footprint and greenhouse gas emissions. It refers to the effects on the nation's carbon footprint and greenhouse gas emissions of its transition from a cash crop economy to an alternative economy. Increased energy demand, altered land use, technological advancements with the potential to enable cleaner practices, changes in consumption patterns, problems with waste generation and management, the introduction of emission regulations and policies are all common effects of industrialization. Countries must prioritize sustainable development policies to lessen the effects on the environment, which include implementing cleaner technology, boosting renewable energy, enforcing emission controls, and promoting energy efficiency and waste reduction initiatives.

Countries place a high priority on sustainable development to ensure long-term economic growth while tackling issues like natural catastrophes and erratic food security. This entails encouraging economic development while protecting the environment, diversifying the economy, investing in renewable energy, resource efficiency, innovation, and technology, being resilient to natural disasters, practicing sustainable agriculture, promoting social inclusivity, and putting into practice green policies and regulations. By implementing these sustainability principles, economies may pursue robust and successful growth while avoiding environmental damage and safeguarding the wellbeing of people and the world. Since natural disasters and unstable food security are the world's top concerns, increasing GDP through Carbon footprint does not guarantee sustainable economic growth. Which economy is preferable to secure long-term economic growth?

The Inverted U-shaped EKC hypothesis postulates a non-linear link between environmental deterioration, particularly carbon footprint, and economic progress. Environmental deterioration increases initially when economies grow and become more industrialized. Beyond a certain point in economic advancement, the trend, however, reverses, and environmental degradation starts to decline as a result of raised environmental awareness and the adoption of cleaner technologies and policies. If an investigation reveals an impartial association between the carbon footprint and cash crop-based economic development, it suggests that the relationship between these two variables is not significant and does not follow the EKC pattern.

*Hypothesis 1: Based on EKC, there is an insignificant correlation exists between cash crop-based economic development and the carbon footprint.*

*Hypothesis 2: EKC has an inverted U shape affiliation between carbon footprint and industrialized economic growth.*

## 2. Materials and Methods

**2.1. Literature review.** Carbon footprint is a global problem that needs to be addressed if a sustainable society is to be built. Previously related studied conducted and some of them are very interesting. According to research [8], GDP and Carbon footprint in Algeria have a significant relationship between 1970 and 2010. In bivariate and multivariate models for Pakistan's 1971–2019 period [9] used the autoregressive distributed lag model (ARDL) and Johansen cointegration to investigate the connection between Carbon footprint, energy use, and economic progress. These results show that a rapidly expanding economy and energy use have a positive and significant impact on Carbon footprint. The relationship between the use of renewable energy, economic growth, and Carbon footprint for a group of seven countries was examined [10] using the ARDL limit test. It is demonstrated that cointegration exists in the G7 countries when real GDP per capita and Carbon footprint are used as dependent variables. In [11] examined the connection between Carbon footprint, energy use, and GDP at the state level in the United States from 1997 to 2016 where the results demonstrate a long-term relationship between various forms of energy consumption and Carbon footprint for both static and dynamic models. In investigation [12] looked at the relationship between Carbon footprint, energy consumption, GDP, and trade liberalization. This statistic shows that energy use and trade liberalization have a single-direction causal relationship with GDP and Carbon footprint. The contribution of several major energy sources (oil, coal, natural gas, hydroelectricity, and other renewables) to global Carbon footprint was examined in a study [13]. In [14] the relationships examined among Carbon footprint, energy consumption, economic growth, exports, and population density in 11 Asian states between 1960 and 2014 in order to assess the long-term effects on Carbon footprint using FMOLS and dynamic ordinary least squares (DOLS) methods. The test results suggest that these five factors have been cointegrated over time. Study in Indonesia [15], in France [16], and in Malaysia [17]

all revealed how economic growth affects energy use and Carbon footprint. Many recent studies have employed the KOF index to examine how globalization has affected Carbon footprint [18–20]. The analysis of the trajectory of Carbon footprint in Iran, Canada, and Italy using a general regression neural network (GRNN) and grey wolf optimization (GWO), and the results demonstrate that the recommended technique is more accurate in long-term Carbon footprint forecasting. Iran's Carbon footprint were predicted in 2030 using time series and regression analysis [21]. Based on their results, Iran is unlikely to adhere to the Paris Agreement if business continues as usual (BAU). By using a general regression neural network (GRNN) and grey wolf optimization (GWO) to assess the trend of Carbon footprint in Iran, Canada, and Italy, and the findings show that the suggested method is more accurate in long-term Carbon footprint forecasting [20]. According to findings [21], Iran is unlikely to keep its goal to the Paris agreement based on the business as usual (BAU's) assumptions. A deep learning hybrid approach was utilized in India to forecast Carbon footprint [22]. The prediction was made using a deep learning hybrid model convolutional neural network-long short-term memory (CNN-LSTM). By using the simple exponential smoothing (SES) and autoregressive integrated moving average (ARIMA) models try to predict Carbon footprint. Since the ARIMA model has the lowest fractional mean absolute error (FMAE) value, they found that it is suitable.

Prior research on the EKC theory has mostly concentrated on the GDP as a whole; however, the sectoral EKC has received less attention [23]. The construction sector, other economic activities, and the agricultural, forestry, and fisheries industries all had a U-shaped EKC established by the study; however, the manufacturing and transportation sectors had an inverted U-shaped relationship. It is also examined the sectoral EKC for OPEC nations and came to the conclusion that there was a positive correlation between the value-added in the manufacturing sector and Carbon footprint, but a negative correlation between the value-added in agricultural and Carbon footprint [24]. However, it is discovered a contradictory finding for the value-added of the service sector, with the short-term reduction of Carbon footprint outweighing the long-term contribution to Carbon footprint. Additionally, in [25] the investigation of the EKC hypothesis for sub-sectors in the service industry after looking at aggregated value-added findings, which showed that the EKC hypothesis was supported by aggregated value-added results but not by sub-sectors. Authors of [26, 27] showed sectoral EKC for Portugal and came to conflicting conclusions on the relationship between sectoral value-added and Carbon footprint supporting both the N-shaped and inverted U-shaped associations. To account for the above, prior research has indicated that the sectoral EKC's impact on Carbon footprint is varied that necessitates more research. In contrast to sectoral EKC, several research evaluated the EKC hypothesis while additionally using a sectoral value-added variable to account for the sectoral effect. These studies likewise produced a variety of outcomes [28–35]. It was investigated the harm that agriculture was doing to the environment. In African countries [36], Pakistan [37], G20 countries [35], Nigeria [38], E7 countries [39], and in Azerbaijan [40] supported the EKC theory, however, the relationship between the value-added to agricultural and Carbon footprint is not unambiguous. Some research looked at other industries outside agriculture to evaluate the link. In [41] studied how South Asian nations' GDP value-added in the manufacturing, service, and agricultural sectors impacted Carbon footprint, finding a negative correlation for agriculture and a positive correlation for those in the manufacturing and service sectors. In [42] supported the favorable correlate for industry sector value-added across twenty emerging economies. In [43] looked into the relationship between manufacturing sector value-added and discovered a favorable correlation. Despite the sectoral value-added's inclusion in the EKC model, the outcomes is inconsistent and for the purpose of measuring the effect precisely, more research based on the sectoral EKC model is required. Energy consumption increases Carbon footprint. Some studies focused on the relationship between renewable energy and Carbon footprint [44–48] or the environmental aspects of alternative energy usage due to the negative effects of the energy-intensive sectors [48]. For instance, [49] discovering a causal link between population growth and Carbon footprint, as well as renewable energy (RE). The per capita use of renewable energy and carbon footprint are negatively correlated, although the per capita GDP is favorably correlated [50]. Long-term usage of renewable energy is beneficial in lowering consumption-based Carbon footprint [51]. Long-term Carbon footprint was greatly reduced by renewable energy, as demonstrated. Table 1 shows the summary of recent studies.

**Table 1**

Summary of recent studies

| Source | Method, Country | Period | Result |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| [52] | Second- and third generation panel cointegration/7 emerging countries | 1995–2018 | In both the short term and long term, imports and economic growth increase Carbon footprint, while financial instability, technological innovation, and exports significantly decrease consumption-based Carbon footprint |
| [53] | OLS, FMOLS/182 countries | 1990–2015 | Trade openness reduces carbon footprint in high-income and upper middle-income countries, while rises in low-income countries. For low-middle-income countries, there is no significant relation |
| [51] | Panel regression, quantile regression/22 developed, and developing countries | 1991–2016 | The outcome of agriculture has a positive and significant effect on Carbon footprint from liquid with a 36.75 % increase in environmental degradation and a negative impact on Carbon footprint in the total emissions by 19.12 % |
| [54] | Structural fracture unit root tests, ARDL, Toda-Yamamoto causality test/Turkey | 1968–2016 | There is cointegration. In the long term, Carbon footprint is diminished by agriculture value-added and agricultural land. The EKC holds for Turkey |
| [49] | Panel cointegration and Granger causality/13 developed and developing countries in Asia Pacific Region | 2005–2017 | AGR↔GDP In the short run, the causality between agriculture and $CO_2$ is bidirectional. The causality between renewable energy, population, and Carbon footprint is one-way |

Continuation of Table 1

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| [55] | Granger causality, Panel cointegration/115 countries | 1990–2016 | There is no significant relation between agricultural GDP growth and Carbon footprint for lower middle-, upper middle-, and high-income countries, whereas the relationship is significant and positive for low-income countries |
| [53] | CS-ARDL/G7 countries | 1996–2017 | Economic globalization, financial development, and natural resources have a positive impact on carbon footprint, while agriculture value-added has an inverse impact |
| [56] | FMOLS, DOLS, CCR/Australia | 1972–2014 | In the long run, the relation between expansionary commercial policy and Carbon footprint is significant and positive. While contractionary commercial and monetary policies are able to diminish Carbon footprint, remittance, and fossil fuel increase |
| [57] | China | 2013–2016 | The carbon footprint trading policy has a positive effect on a firm's environmental innovation that supports carbon reduction innovation |
| [58] | Cointegration test, auto regressive distributed lag test/Malaysia | 1978–2016 | In the long run, the relation between economic growth and urbanization and Carbon footprint is positive and significant, while the relation is also positive but insignificant for livestock. Specifically, crops, fisheries, and renewable energy significantly and inversely affect Carbon footprint. The EKC holds |
| [59] | The EU land use futures model (EULUF)/EU-28 | – | The greenhouse gas emissions can be reduced by shifting to more vegetarian diets, decreasing food waste, and rising in crop and livestock yields and land multiuse |
| [60] | The gross export decomposition methodology and the world input-output database/EU | – | Carbon footprint embedded in value-added trade can decrease Carbon footprint because of the repetitive passing of intermediate products over numerous borders |
| [51] | Augmented mean group (AMG) and common correlated effect mean group (CCEMG) methods, second-generation panel cointegration methodologies/G7 countries | 1990–2017 | In the long term, the relation between Carbon footprint and trade, income, environmental innovation, and the renewable energy consumption is stable. Imports and income increase consumption-based carbon footprint, whereas exports, environmental innovation, and renewable energy consumption decrease it |
| [29] | Carbon decomposition model, panel data/China | 1995–2009 | The effect of embedding in the global value chain (GVC) on the carbon footprint of China's exports is analyzed and concluded that GVC is one of the reasons for high carbonization in manufacturing exports |
| [42] | Improved panel GMM/24 emerging economies | 2000–2017 | The EKC holds for nitrous oxide emissions but not for Carbon footprint and fossil fuel energy consumption. Industry value-added raises $CO_2$ and nitrous oxide emissions, while it decreases fossil fuel energy consumption |
| [32] | ARDL, VECM causality/Brazil | 1980–2013 | AGR↔$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is bidirectional |
| [33] | ARDL, Granger causality/South Africa | 1990–2013 | AGR→$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is one-way |
| [35] | Panel FMOLS, VECM causality/G20 countries | 1990–2014 | AGR→$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is one-way |
| [51] | Johansen cointegration, ARDL, Granger causality/Pakistan | 1961–2014 | In the long run, the relation between Carbon footprint, land under cereal crops, and agriculture value-added is positive and insignificant, while in the short run, the relation between $CO_2$ and GDP is negative and insignificant |
| [61] | Structural VAR model/Turkey | 1965–2017 | The relation between economic growth and the primary energy consumption and the carbon footprint is positive, and the primary energy consumption has more effect on carbon footprints than growth. Moreover, the impact of growth on primary energy consumption is positive and permanent |
| [62] | Agglomerative cluster analysis, the random forest algorithm/Eindhoven, Netherlands | – | The effect of different categories of land use on carbon footprints is analyzed. The contribution of the retail trade and residential land use categories to carbon footprints is larger than other categories. Among the residential building category, terrace houses contribute the most |
| [34] | Panel PMG, MG, AMG/Central and West African countries | 1996–2015 | AGR↔$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is bidirectional |
| [31] | ARDL, FMOLS, DOLS, VECM/Pakistan | 1990–2014 | AGR→$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is one-way |
| [30] | Pedroni cointegration, DOLS, FMOLS, PMG/emerging countries | 1971–2013 | AGR↔$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is bidirectional |
| [63] | Johansen, Toda Yamamoto causality, FMOLS, CCR/Pakistan | 1981–2015 | No causal relation found between agriculture and $CO_2$ |
| [64] | Panel data analysis/81 countries | 1995–2013 | The effect of carbon footprints on economic growth is significant and positive. The rise in the use of primary energy resources in the industry due to economic development has raised the carbon footprints and hence the economic growth |
| [65] | GMM, DOLS/Turkey | 1960–2014 | EKC hypothesis holds. Energy consumption and Carbon footprint are positively related |
| [29] | Pedroni cointegration, FMOLS, DOLS, VECM causality/ASEAN countries | 1970–2013 | AGR→$CO_2$. There is cointegration. The causality between agriculture and $CO_2$ is one-way |
| [66] | PVAR, panel effect-response function model/106 countries | 1971–2001 | The relation between economic growth and energy consumption is bidirectional and the effect of energy consumption on economic growth and Carbon footprint is heterogeneous |

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| [67] | PVAR/BRICT countries | 1990–2015 | The causality between GDP and urbanization, renewable energy, oil prices, and carbon footprints is one-way |
| [68] | Johansen cointegration and Granger causality/MIST countries | 1971–2010 | The causality between economic growth and Carbon footprint and energy consumption is one-way |
| [69] | ARDL/Italy | 1960–2011 | In both the short run and long run, renewable energy consumption reduces Carbon footprint, whereas, in the long run, international trade increases Carbon footprint |
| [70] | GMM/58 countries | 1990–2012 | Carbon footprint and energy consumption are positively related, while the effect of growth on energy consumption is positive and significant |
| [50] | ADF, Johansen cointegration/Turkey | 1990–2012 | One-way causality exists between per capita consumption of renewable energy and per capita carbon footprints. Furthermore, the relation between per capita consumption of renewable energy and carbon footprint is negative, while the relation between per capita GDP and per capita carbon footprints is positive |
| [71] | ARDL/Turkey | 1961–2010 | In the long run, the relation between electricity production from renewable sources, excluding hydropower and Carbon footprint, is inverse and significant |
| [41] | Regression analysis/South Asian countries | 1972–2010 | The effect of agriculture value-added on Carbon footprint is negative and significant, while the impact is positive and significant for industrial and services value-added. The EKC does not hold |

**2.2. Theory, data and model.** The dramatic increase in greenhouse gas, mainly Carbon footprint, during the past few years is the primary contributor to the current serious environmental issue, warming around the world. In order to examine the relationship among all examined variables, the descriptive statistics conducted including the carbon footprint ($CO_2$), agriculture gross value added, industry gross value added, service gross value added, manufacturing gross value added, export value-added, foreign direct investment, trade openness, and labor force participation percentage. To assist in the mobilization of stationarity, natural logarithms (ln) have been used to all variables. EKC model, developed by Grossman and Krueger in 1995, suggests a non-linear relationship between environmental deterioration and economic growth. According to this theory, when an economy expands and develops, its effects on the environment first deteriorate, but after reaching a particular stage of economic growth, environmental degradation begins to improve. An inverted U-shaped curve is a typical graphic representation of the EKC model. The curve demonstrates that initially, envi-

ronmental deterioration grows as a country's GDP per capita increases. The «ascending limb» of the curve is what is referred to as this stage. Beyond a certain point in economic development, however, the curve turns, and as the economy expands further, environmental degradation starts to decline. The «descending limb» of the curve is what we refer to as this stage. To analyze the EKC let's regress raw variable with squire term of this variable. Consequently, employing descriptive statistics for the dependent and independent variables, the study's econometric model is as follows:

*Carbon footprint=f(agriculture, industry, service, manufacturing, export, fdi, trade openness, labor force participation).*

*Carbon footprint=$\beta_0+\beta_{1agriculture}+\beta_{2industry}+\beta_{3service}+$*
*$+\beta_{4manufacturing}+\beta_{5export}+\beta_{6fdi}+\beta_{8trade\ openness}+$*
*$+\beta_{9labor\ force\ participation\ percentage}+\in_{it}$.*

Table 2 shows the explained and explanatory Variables.

**Table 2**

Explained and explanatory Variables

| Explained and explanatory Variables | Definition | Unit of measurement | Logarithmic forms | Source |
|---|---|---|---|---|
| Carbon footprint ($CO_2$) | Damage to the environment due to Carbon footprint | Million tonnes | LCP | WDI |
| Greenhouse gas (GHG) | Damage to the environment due to greenhouse gas | Million tonnes | LGG | WDI |
| Economic growth (GPC) | Representing the GDP per capita | Current USD in million | LGPC | WDI |
| Agriculture gross value-added (AGC) | Representing the agriculture, forestry, and fishing sector | USD in million | LAGC | WDI |
| Industry gross value added (IGC) | Representing the industry and manufacturing sector | USD in million | LIGC | WDI |
| Service gross value added (SGC) | Representing the service sector | USD in million | LSGC | WDI |
| Manufacturing gross value added (MGC) | Representing manufacturing sector | USD in million | LMGC | WDI |
| Export value-added (EXC) | Representing the value of exported goods and services | USD in million | LEXC | WDI |
| Foreign direct investment (FDI) | Representing the net inflows | USD in million | LFDI | WDI |
| Trade openness (TRO) | Sum of exports and imports of goods and services | USD in million | LTRO | WDI |
| Labor force participation (PLP) | Representing the percentage of labor force participation | Percentage of people | LPLP | WDI |

## 3. Results and Discussion

Since obtaining a desirable growth rate is one of the fundamental economic objectives, GDP growth is one of the important macroeconomic factors that determine a country's policies. However, it is impossible to ignore ecological and environmental implications. The link between economic growth and carbon footprint has so lately attracted the attention of policymakers, practitioners, and scholars. An inverted U-shaped link between economic development and carbon footprint is suggested by the Environmental Kuznets Curve (EKC) theory, which has received support from certain recent research. The earliest studies contend that economic development leads to environmental deterioration up until a certain point and that, after that point, environmental quality increases were those [72]. Conceptually, it is true that the majority of nations are attempting to transition from cash crop economies to industrialized economies, and that the carbon footprint is now a very significant concern; nevertheless, this trend began long ago among rich countries following the industrial revolution. A country's entire output of completed goods and services during a certain period of time, often a year or quarter, is measured as its gross domestic product, or GDP. This makes it a measurement of domestic output and a tool for assessing the state of an economy. A country's GDP, which calculates the value added to each industry, is made up of three different sectors: agriculture, industry, and services. In countries where value added is recorded at basic prices, net indirect taxes are reported as a distinct line item. The value-added shares for industry, services, and agriculture are included in the World Development Indicators as a subset of industry, which includes manufacturing. All the information about the variables, observations, mean, standard deviation, minimum and maximum amount is provided in Table 3.

In Table 4, all the variables have a strong positive linear connection, as seen by their correlation coefficients, which are all more than 0.9. Since correlation does not indicate causality, it is imperative to proceed with caution when examining correlations among variables. Correlation does not establish a cause-and-effect link, even if it indicates the direction and strength of a linear relationship between two variables; however, they indicate that they are linked with one another. An increase in agriculture, industry, service, manufacturing, export, FDI, trade openness, labor force participation activities may lead to an increase in carbon footprint levels.

In Table 5 the descriptive statistics conducted with all examined variables, including the carbon footprint, agriculture gross value added, industry gross value added, service gross value added, manufacturing gross value added, export value-added, foreign direct investment, trade openness, and labor force participation percentage, are critically described. All estimations in this model employ the log transformation of all variables. There are a total of 33 observations made during a 33-year period, from 1990 to 2022, with the highest averages in case of dependent variable for the service, industrial, and trade openness. While the minimal range of the standard deviation for the other five variables is less than one, the standard deviation for export, FDI, and trade openness is greater than one. The descriptive statistics conclude that the behaviors of variables are acceptable and reliable.

**Table 3**

Summary model descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Carbon footprint | 33 | 44174.821 | 28402.682 | 10830.76 | 95944.602 |
| Agriculture | 33 | 20548.157 | 13059.801 | 9024.86 | 51623.512 |
| Industry | 33 | 39285.92 | 43322.72 | 6365.68 | 156100.55 |
| Manufacturing | 33 | 25168.398 | 27715.994 | 4183.37 | 100161.92 |
| Services | 33 | 69854.642 | 64786.247 | 13731.91 | 234877.77 |
| Exports | 33 | 18560.489 | 16192.267 | 1866.93 | 59284.129 |
| FDI | 33 | 944.517 | 930.199 | 1.39 | 2831.15 |
| GDP pc | 33 | 883.218 | 717.954 | 283.38 | 2688.3 |
| Trade openness | 33 | 45354.002 | 40446.73 | 5847.82 | 155455.75 |
| Labor force | 33 | 53.622 | 11.164 | 35.66 | 74.46 |

**Table 4**

Correlation equation summary descriptive statistics

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| (1) $l_{carbon\_foot}$ | 1.000 | – | – | – | – | – | – | – | – |
| (2) $l_{agriculture}$ | 0.937 | 1.000 | – | – | – | – | – | – | – |
| (3) $l_{industry}$ | 0.959 | 0.994 | 1.000 | – | – | – | – | – | – |
| (4) $l_{services}$ | 0.975 | 0.987 | 0.996 | 1.000 | – | – | – | – | – |
| (5) $l_{manufacturing}$ | 0.955 | 0.994 | 1.000 | 0.994 | 1.000 | – | – | – | – |
| (6) $l_{exports}$ | 0.991 | 0.939 | 0.959 | 0.975 | 0.956 | 1.000 | – | – | – |
| (7) $l_{fdi}$ | 0.905 | 0.764 | 0.805 | 0.847 | 0.798 | 0.909 | 1.000 | – | – |
| (8) $l_{trade\_openness}$ | 0.990 | 0.953 | 0.969 | 0.982 | 0.966 | 0.998 | 0.893 | 1.000 | – |
| (9) $l_{labor\_force}$ | 0.986 | 0.933 | 0.961 | 0.976 | 0.957 | 0.982 | 0.904 | 0.981 | 1.000 |

**Table 5**

Log summary equation descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| $l_{carbon\ foot}$ | 33 | 10.468 | 0.713 | 9.29 | 11.472 |
| $l_{agriculture}$ | 33 | 9.763 | 0.565 | 9.108 | 10.852 |
| $l_{industry}$ | 33 | 10.065 | 0.999 | 8.759 | 11.958 |
| $l_{services}$ | 33 | 10.766 | 0.888 | 9.527 | 12.367 |
| $l_{manufacturing}$ | 33 | 9.625 | 0.991 | 8.339 | 11.515 |
| $l_{exports}$ | 33 | 9.374 | 1.036 | 7.532 | 10.99 |
| $l_{fdi}$ | 33 | 5.559 | 2.368 | 0.329 | 7.948 |
| $l_{trade\ openness}$ | 33 | 10.279 | 1.005 | 8.674 | 11.954 |
| $l_{labor\ force}$ | 33 | 3.961 | 0.212 | 3.574 | 4.31 |

In Table 6, it shows that the coefficient of GDP per capita titled «cgdp_pc2» will represent the curvature of the EKC relationship between «carbon_footprint» and «cgdp_pc» (Fig. 1). For a one-dollar increase in GDP per capita centered «cgdp_pc», the «carbon_footprint» is expected to increase by 58.15 million kg, holding all other variables constant and it is significant at 1 % level ($p\text{-}value < 0.001$). This suggests a positive relationship between economic development and carbon footprint. For a one-dollar increase in GDP per capita in the squared «cgdp_pc2», the «carbon_footprint» is expected to decrease by 0.024 million kg, holding all other variables constant

and it is significant at 1 % level ($p\text{-}value < 0.001$). This suggests a quadratic relationship between GDP per capita and carbon footprint, following an inverted U-shaped environmental Kuznets curve pattern.

In Table 7, it shows that the coefficient of agriculture squire will represent the curvature of the EKC relationship between «carbon_footprint» and «agriculture» (Fig. 2). For a one million dollar increase in agriculture, the «carbon_footprint» is expected to increase by 2.97 million kg, holding all other variables constant and it is significant at 1 % level ($p\text{-}value < 0.001$). This suggests a positive relationship between agricultural development and carbon footprint. For a one-dollar increase in agriculture in the squared, the «carbon_footprint» is expected to decrease by 0.0000646 million kg, holding all other variables constant and it is significant at 1 % level ($p\text{-}value < 0.001$). This suggests a quadratic relationship between agriculture and carbon footprint, following an inverted U-shaped environmental Kuznets curve pattern. However, the coefficient of agriculture squire ($β_2$) is negative and close to zero ($-0.0000646$) which shows EKC has not a more pronounced inverted U shape affiliation between carbon footprint and agriculture value addition to GDP. The statistical significance of $β_2$ is crucial to figure out whether the curvature in the relationship is meaningful and not due to random chance. A statistically significant $β_2$ strengthens the case for the presence of an EKC pattern. The magnitude of $β_2$ indicates the strength of the curvature in the relationship. A larger absolute value of $β_2$ suggests a more pronounced U-shaped or inverted U-shaped relationship.

**Table 6**

Linear regression on environmental Kuznets curve (EKC) equation

| carbon_footprint | Coef. | St. Err. | $t$-value | $p$-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $c_{gdp\_pc}$ | 58.152 | 1.376 | 42.26 | 0 | 55.342 | 60.962 | *** |
| $c_{gdp\_pc2}$ | −0.024 | 0.001 | −18.49 | 0 | −0.027 | −0.022 | *** |
| Constant | 56377.388 | 846.521 | 66.60 | 0 | 54648.561 | 58106.214 | *** |
| Mean dependent var | 44174.821 | | SD dependent var | | | 28402.682 | |
| R-squared | 0.989 | | Number of obs | | | 33 | |
| F-test | 1375.587 | | Prob > F | | | 0.000 | |
| Akaike crit. (AIC) | 625.943 | | Bayesian crit. (BIC) | | | 630.433 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
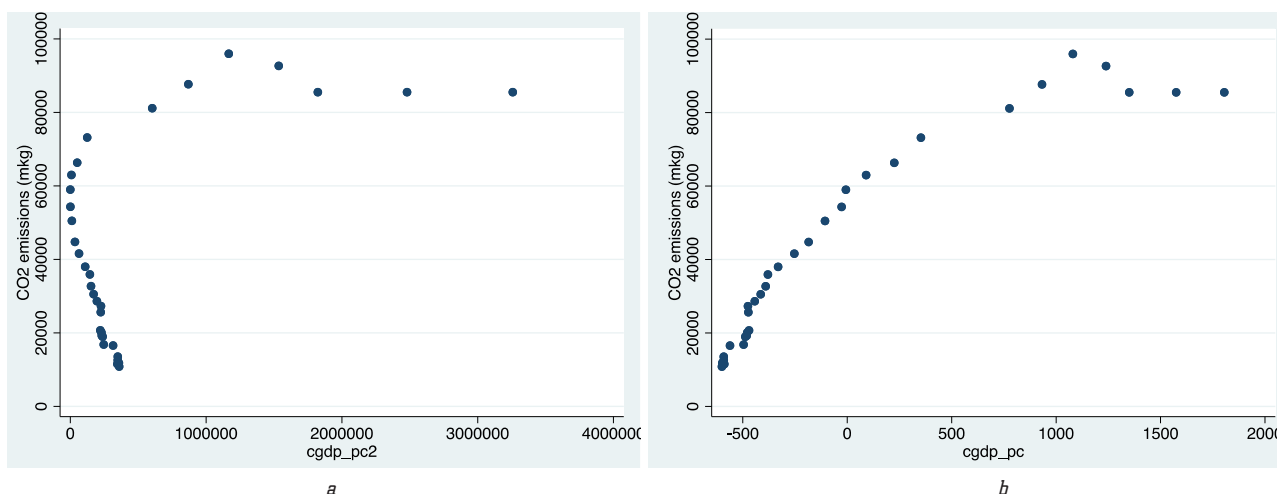


a



b

**Fig. 1.** Relationship between GDP per capita and carbon footprint: $a - c_{gdp\_pc2}$; $b - c_{gdp\_pc}$

**Table 7**

Linear regression on environmental Kuznets curve (EKC) equation

| carbon_footprint | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $c_{agriculture}$ | 2.975 | 0.086 | 34.71 | 0 | 2.8 | 3.15 | *** |
| $c_{agriculture2}$ | −0.0000646 | 0 | −13.10 | 0 | 0 | 0 | *** |
| Constant | 54851.94 | 1034.04 | 53.05 | 0 | 52740.149 | 56963.731 | *** |
| Mean dependent var | 44174.821 | | SD dependent var | | | 28402.682 | |
| R-squared | 0.984 | | Number of obs | | | 33 | |
| F-test | 950.176 | | Prob > F | | | 0.000 | |
| Akaike crit. (AIC) | 637.994 | | Bayesian crit. (BIC) | | | 642.483 | |

**Notes:** *** $p<0.01$, ** $p<0.05$, * $p<0.1$



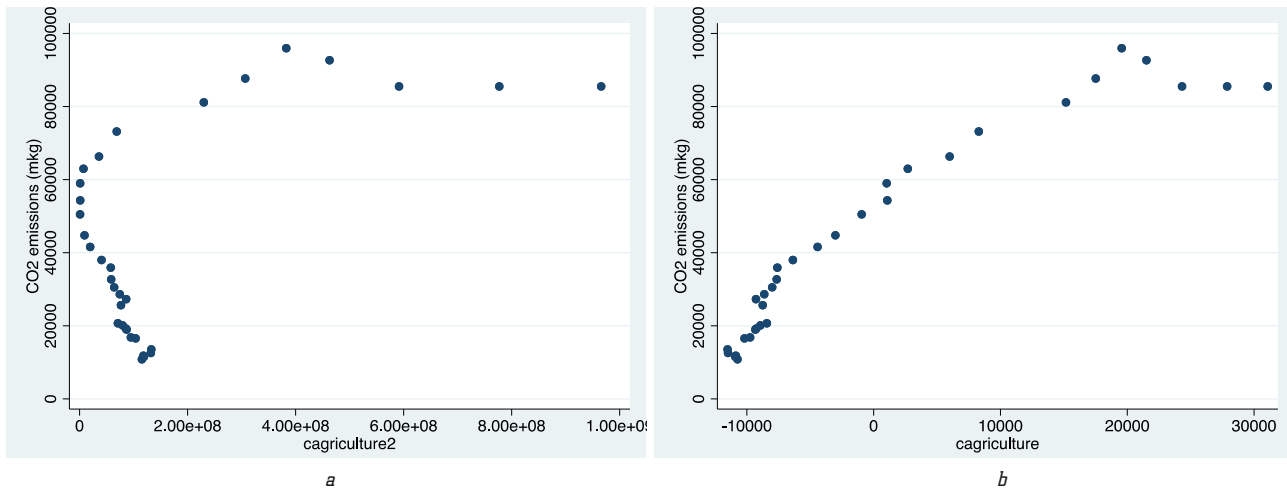*a*                                                    *b*

**Fig. 2.** Relationship between agriculture and carbon footprint: $a - c_{agriculture2}$; $b - c_{agriculture}$

In Table 8, it shows that the coefficient of industry squire stands for the curvature of the EKC relationship between (Fig. 3). For a one million dollar increase in industry, the «carbon_footprint» is expected to increase by 1.06 million kg, holding all other variables constant and it is significant at 1 % level (*p-value* < 0.001). However, the coefficient of industry squire ($β_2$) is negative and a larger absolute value (7.7) which shows EKC has a more pronounced inverted U shape affiliation between carbon footprint and industry value addition to GDP. The magnitude of $β_2$ indicates the strength of the curvature in the relationship and a larger absolute value of $β_2$ suggests a more pronounced U-shaped or inverted U-shaped relationship.

In Table 9, it shows that the coefficient of service squire stands for the curvature of the EKC relationship between (Fig. 4). For a one million dollar increase in service, the «carbon_footprint» is expected to increase by 0.63 million kg, holding all other variables constant and it is significant at 1 % level (*p-value* < 0.001). However, the coefficient of service squire ($β_2$) is negative and an absolute value (2.8) which shows EKC has a moderate pronounced inverted U shape affiliation between carbon footprint and service value addition to GDP. The magnitude of $β_2$ indicates the strength of the curvature in the relationship and a larger absolute value of $β_2$ suggests a more pronounced U-shaped or inverted U-shaped relationship.

**Table 8**

Linear regression on environmental Kuznets curve (EKC) equation

| carbon_footprint | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $c_{industry}$ | 1.065 | 0.036 | 29.71 | 0 | 0.992 | 1.138 | *** |
| $c_{industry2}$ | −7.79 | 0 | −15.27 | 0 | 0 | 0 | *** |
| Constant | 58352.072 | 1197.374 | 48.73 | 0 | 55906.708 | 60797.435 | *** |
| Mean dependent var | 44174.821 | | SD dependent var | | | 28402.682 | |
| R-squared | 0.978 | | Number of obs | | | 33 | |
| F-test | 669.295 | | Prob > F | | | 0.000 | |
| Akaike crit. (AIC) | 649.343 | | Bayesian crit. (BIC) | | | 653.833 | |

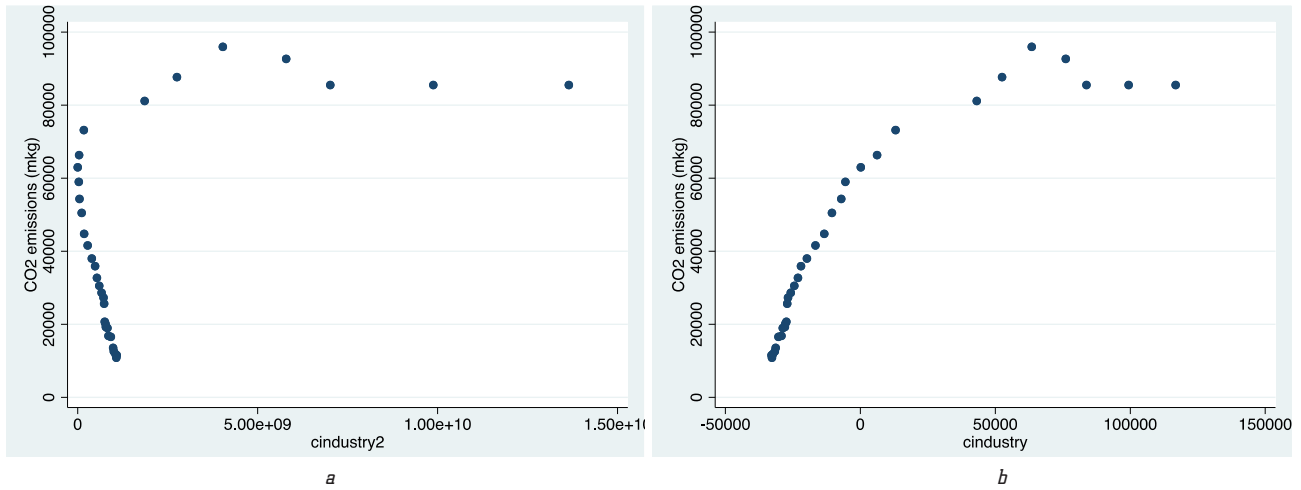**Notes:** *** $p<0.01$, ** $p<0.05$, * $p<0.1$

**Fig. 3.** Relationship between industry and carbon footprint: $a - c_{industry2}$; $b - c_{industry}$

**Table 9**

Linear regression on environmental Kuznets curve (EKC) equation

| carbon_footprint | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $c_{services}$ | 0.63 | 0.012 | 54.31 | 0 | 0.607 | 0.654 | *** |
| $c_{services2}$ | −2.83 | 0 | −23.21 | 0 | 0 | 0 | *** |
| Constant | 55689.205 | 651.443 | 85.49 | 0 | 54358.781 | 57019.629 | *** |
| Mean dependent var | 44174.821 | | | SD dependent var | | | 28402.682 |
| R-squared | 0.993 | | | Number of obs | | | 33 |
| F-test | 2180.345 | | | Prob > F | | | 0.000 |
| Akaike crit. (AIC) | 610.875 | | | Bayesian crit. (BIC) | | | 615.364 |

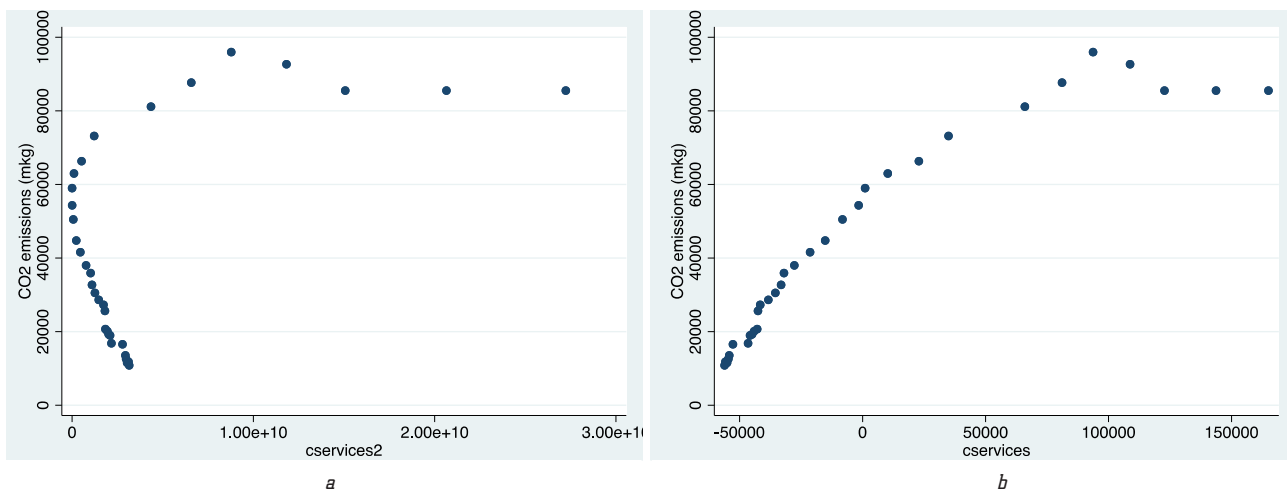**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$



**Fig. 4.** Relationship between service and carbon footprint: $a - c_{services2}$; $b - c_{services}$

In Table 10, it shows that the coefficient of manufacturing squire stands for the curvature of the EKC relationship between (Fig. 5). For a one million dollar increase in manufacturing, the «carbon_footprint» is expected to increase by 1.67 million kg, holding all other variables constant and it is significant at 1 % level ($p$-$value < 0.001$). However, the coefficient of manufacturing squire ($\beta_2$) is close to zero (−0.0000191) which shows EKC has an insignificant inverted U shape affiliation between carbon footprint and manufacturing value addition to GDP. The magnitude of $\beta_2$ indicates the strength of the curvature

in the relationship and a larger absolute value of $\beta_2$ suggests a more pronounced U-shaped or inverted U-shaped relationship. It is noted that manufacturing is belonging to Industry.

Additionally, Tables 11–15 make it abundantly evident that, with the exception of Agriculture Gross Value-Added (AGC), all other variables have positive, substantial effects on carbon footprint, making each variable individually accountable for carbon footprints and environmental degradation; however, combined results shown in Table 15 are slightly different.

**Table 10**

Linear regression on environmental Kuznets curve (EKC) equation

| carbon_footprint | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $c_{manufacturing}$ | 1.665 | 0.06 | 27.55 | 0 | 1.542 | 1.789 | *** |
| $c_{manufacturing2}$ | −0.0000191 | 0 | −14.14 | 0 | 0 | 0 | *** |
| Constant | 58367.069 | 1289.607 | 45.26 | 0 | 55733.341 | 61000.797 | *** |
| Mean dependent var | 44174.821 | | | SD dependent var | | 28402.682 | |
| R-squared | 0.975 | | | Number of obs | | 33 | |
| F-test | 581.430 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | 653.878 | | | Bayesian crit. (BIC) | | 658.368 | |

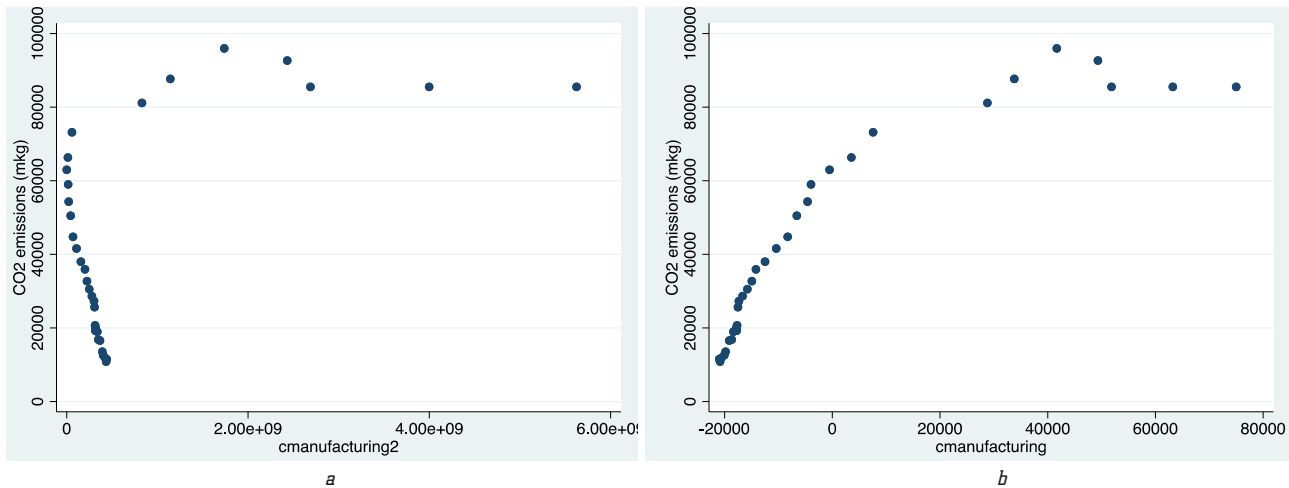**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$



**Fig. 5.** Relationship between manufacturing and carbon footprint: $a - c_{manufacturing2}$; $b - c_{manufacturing}$

**Table 11**

Linear regression agc model equation summary statistics

| $l_{carbon\_foot}$ | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $l_{gdp\_pc}$ | 3.125 | 0.704 | 4.44 | 0 | 1.687 | 4.564 | *** |
| $l_{agriculture}$ | −2.801 | 0.9 | −3.11 | 0.004 | −4.639 | −0.963 | *** |
| Constant | 17.464 | 4.224 | 4.13 | 0 | 8.838 | 26.091 | *** |
| Mean dependent var | 10.468 | | | SD dependent var | | 0.713 | |
| R-squared | 0.927 | | | Number of obs | | 33 | |
| F-test | 189.767 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | −9.935 | | | Bayesian crit. (BIC) | | -5.445 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

**Table 12**

Linear regression on igc model equation summary statistics

| $l_{carbon\_foot}$ | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $l_{gdp\_pc}$ | −2.459 | 0.846 | −2.91 | 0.007 | −4.188 | −0.731 | *** |
| $l_{industry}$ | 2.458 | 0.611 | 4.02 | 0 | 1.21 | 3.707 | *** |
| Constant | 1.736 | 0.716 | 2.42 | 0.022 | 0.273 | 3.199 | ** |
| Mean dependent var | 10.468 | | | SD dependent var | | 0.713 | |
| R-squared | 0.937 | | | Number of obs | | 33 | |
| F-test | 223.216 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | −14.928 | | | Bayesian crit. (BIC) | | -10.438 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 13

Linear regression on SGC model equation summary statistics

| $l_{carbon\_foot}$ | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $l_{gdp\_pc}$ | −1.64 | 0.213 | −7.69 | 0 | −2.076 | −1.204 | *** |
| $l_{services}$ | 2.109 | 0.173 | 12.16 | 0 | 1.755 | 2.463 | *** |
| Constant | −1.561 | 0.51 | −3.06 | 0.005 | −2.602 | −0.52 | *** |
| Mean dependent var | 10.468 | | | SD dependent var | | 0.713 | |
| R-squared | 0.984 | | | Number of obs | | 33 | |
| F-test | 902.429 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | −59.425 | | | Bayesian crit. (BIC) | | −54.935 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 14

Linear regression on mgc model equation summary statistics

| $l_{carbon\_foot}$ | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $l_{gdp\_pc}$ | −1.084 | 0.923 | −1.17 | 0.249 | −2.969 | 0.801 | – |
| $l_{manufacturing}$ | 1.476 | 0.672 | 2.20 | 0.036 | 0.103 | 2.85 | ** |
| Constant | 3.317 | 0.584 | 5.68 | 0 | 2.124 | 4.51 | *** |
| Mean dependent var | 10.468 | | | SD dependent var | | 0.713 | |
| R-squared | 0.917 | | | Number of obs | | 33 | |
| F-test | 164.669 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | −5.620 | | | Bayesian crit. (BIC) | | −1.130 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 15

Linear regression on combine model equation summary statistics

| $l_{carbon\_foot}$ | Coef. | St. Err. | t-value | p-value | [95 % Conf | Interval] | Sig |
|---|---|---|---|---|---|---|---|
| $l_{gdp\_pc}$ | −4.448 | 1.75 | −2.54 | 0.018 | −8.061 | −0.835 | ** |
| $l_{agriculture}$ | 1.017 | 0.613 | 1.66 | 0.11 | −0.248 | 2.282 | – |
| $l_{industry}$ | 1.058 | 0.677 | 1.56 | 0.131 | −0.339 | 2.455 | – |
| $l_{services}$ | 2.743 | 0.942 | 2.91 | 0.008 | 0.8 | 4.687 | *** |
| $l_{exports}$ | 0.253 | 0.431 | 0.59 | 0.564 | −0.0638 | 1.143 | – |
| $l_{fdi}$ | −0.022 | 0.027 | −0.82 | 0.421 | −0.076 | 0.033 | – |
| $l_{labor\_force}$ | −1.476 | 1.151 | −1.28 | 0.212 | −3.852 | 0.9 | – |
| $l_{trade\_openness}$ | −0.075 | 0.443 | −0.17 | 0.867 | −0.989 | 0.84 | – |
| Constant | −6.313 | 3.907 | −1.62 | 0.119 | −14.377 | 1.751 | – |
| Mean dependent var | 10.468 | | | SD dependent var | | 0.713 | |
| R-squared | 0.991 | | | Number of obs | | 33 | |
| F-test | 316.440 | | | Prob > F | | 0.000 | |
| Akaike crit. (AIC) | −65.721 | | | Bayesian crit. (BIC) | | −52.252 | |

**Notes:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

*Legal Obligations and Policy Suggestions.* The Kyoto Protocol to the UNFCCC was adopted in 1997 to introduce more robust legally binding GHG emission reduction targets and timelines, which were absent from the UNFCCC. The Kyoto Protocol entered into force in 2005 and currently has 192 Parties [66]. The essential tenet of the Kyoto Protocol was that industrialized nations needed to lessen the amount of their $CO_2$ emissions. Countries that ratified the Kyoto Protocol were assigned maximum carbon footprint levels for specific periods and participated in carbon credit trading. If a country emitted more than its assigned limit, then it would be penalized by receiving a lower emissions limit in the following period [73]. After that, the Paris Agreement became a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations together to combat climate change and adapt to its effects. Its overarching goal is to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels [74]. The Paris Agreement is organized to respect state sovereignty with a bottom-up

structure of nationally determined contributions (NDCs), which allows Parties to communicate actions taken to reduce their own Green House Gas emissions. To enforce accountability however, there are also structures in place including a transparency system, which contains certain information sharing obligations under Articles 4 and 13; a global stocktake process, which begins in 2023 and involves collective progress tracking and assessment every five years under Article 14; and a compliance mechanism, which designates a committee to facilitate implementation and promotion of compliance under Article 15 [75]. Also, some regional associations of countries, like ASEAN, EU, Pacific countries, and Southeast or South Asian countries have taken regional attempts to reduce carbon footprint based on unified projects. Bangladesh enacted several laws, rules, and policies to address the carbon footprint issue with severe importance but still, there are some loopholes that need to be noticed. Bangladesh should formulate policies regarding sustainable development in the agricultural sector as well as foster industrialization with due care to international legal obligations to mitigate carbon pollution. In the upcoming days, considering the amount of population and the need for development in every sector, such as agriculture, trade, industrialization, service, and manufacture of products, Bangladesh should take appropriate policies which can harmonize all the needs while keeping the carbon footprint at the lowest as possible. Taxation may be imposed on specific trade and business where carbon footprint is at an alarming level. Besides this, the reduction of tax may be provided to those inputs, in agriculture, where carbon footprint is minimal. This strategy may inspire companies to give attention to environmental pollution by reducing carbon footprint. Rigorous research work and analysis are required to determine the execution process of such vast work with the collaboration of government agencies, civil society, NGOs, international communities, local communities as well as educational institutions.

*Practical significance of the research.* The study's findings have significance far beyond Bangladesh's boundaries since they highlight the beneficial carbon reduction potential inherent in agricultural economies while also highlighting the burden of carbon emissions associated with industrial economies. These results have intrinsic significance for an international audience since they cut beyond geographic barriers to provide a thorough foundation for sustainable development. The paper provides an invaluable reference point for governments around the world struggling with the challenge of balancing economic growth with ecological stewardship by assessing the relative environmental effect of various economic sectors. Policymakers and other stakeholders can use the knowledge gained from this research as a guide to help them pursue growth models that put sustainability first. The study's disclosure of the crucial role of agriculture in carbon footprint reduction provides a revolutionary story in a society grappling with the urgency of climate change and its effects. No matter how different their economies and regions are, all nations may learn from Bangladesh's experience and use what they learn to reevaluate their economic strategies and investment choices. It emphasizes the idea that placing a strategic priority on agriculture may help achieve global climate goals set forth in international accords like the Paris Agreement in addition to spurring economic growth.

The study's consequences penetrate the fabric of society awareness and go beyond simple policy issues. A compelling story for lobbying and awareness efforts is the comparison of agriculture's positive carbon footprint impact with the burden of industrial sectors' carbon emissions.

*Limitations and prospects for further research.* While the study effectively highlights the comparative carbon footprint reduction potential of agricultural economies versus carbon emissions from industrial economies, it might have slightly overlooked the broader environmental impacts of agricultural practices beyond carbon, such as water use and pesticide effects. The prospects for further research are promising, with opportunities to conduct life cycle assessments encompassing environmental impacts, explore technological innovations within both sectors, analyze regional variations, delve into circular economy approaches, understand the social and economic dimensions of sustainable transitions, study consumer behavior, assess policy implications comprehensively, and scrutinize long-term trends in economic transformations. These potential research directions can contribute to a more comprehensive and nuanced understanding of the interplay between economic activities and sustainability, enriching policy recommendations and paving the way for more informed decision-making.

## 4. Conclusions

This paper uncovers the significance of the impact of carbon footprint due to agriculture, manufacturing products, services, and other trade-related activities. It shows the interrelation between GDP growth and carbon footprint based on several methods and tests. The current study looked at the relationship between carbon footprint and economic value added from manufacturing, services, industry, and agriculture by adding to the body of literature on EKC. The analysis discovered that adding value to agriculture reduces carbon dioxide emissions. In addition, the study discovered that the EKC hypothesis holds true in terms of the value-added to industry, manufacturing, services, and agriculture. Additionally, the economic contributions of industry, services, and manufacturing result in carbon footprints, whereas the economic contribution of agriculture is ecologically preferable. As a result, there is an inverted U-shaped pattern in the association between carbon footprint and each of industry, service, and manufacturing value added; agriculture, however, shows insignificant inverted U-shaped pattern. In addition, we discovered that every dependent variable – aside from the GDP contribution of agriculture – has a positive connection with carbon footprint. The significance of this study is that it provides policy recommendations to the government and the key players in the industry, service, and agriculture industries. In order to avoid the issue of the present trend of environmental sustainability in the sector, the sustainable approach should be broadened in the area of agriculture. In order to do this, on the one hand, tax policy may be a tried-and-true tool for promoting low-carbon energy usage in the sector, while on the other hand, agricultural policy subsidies and deregulation may work as motivating elements for the growth of the cash crop economy. It is possible to see this as a potential development area in the present study that should be of concern to decision-makers.

## Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

## Financing

The research was performed without financial support.

## Data availability

The manuscript has no associated data.

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