Key Drivers of Consumption-Based Carbon Emissions: Empirical Evidence from SAARC countries

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Key Drivers of Consumption-Based Carbon Emissions: Empirical Evidence from SAARC countries

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Abstract

To devise an appropriate climate policy dealing with environmental degradation, reliable measurement of CO₂ emissions is essential. In the recent past, most researchers have utilized production-based emissions in their studies, ignoring the important role of consumption-based emissions in environmental degradation. Therefore, the present research examines the drivers of consumption-based CO₂ emissions in SAARC nations over the period 1990 to 2018. By employing traditional and second-generation panel cointegration methodologies, the study, more specifically, explores the link between consumption-based CO₂ emissions and its four macroeconomic determinates, namely, GDP growth, energy consumption, FDI, and trade openness (measured by Composite Trade Share Index). The study also applies the FMLOS and DOLS techniques for calculating the long-run elasticities of regressors with respect to the explained variable. The results establish a cointegration relationship between the variables and validate the “EKC hypothesis” for the SAARC region. It is also found that in the long run, as expected, energy consumption enhances the consumption-based CO₂ emissions while FDI and trade openness improve the environmental quality by plummeting emissions. Most importantly, the study rejects the “pollution-haven hypothesis” for the SAARC region based on the negative and statistically significant coefficient of FDI. Lastly, based on the results, some policies are recommended for the abatement of environmental degradation in SAARC countries. As the SAARC nations rely heavily on fossil-based energy, it is suggestive for these economies to enhance the level of energy efficiency and augment the share of renewable energy sources in the energy-mix. Furthermore, the policy-designers in this region should encourage trade openness and liberalize inward FDI for containing consumption-based emissions.

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To devise an appropriate climate policy dealing with environmental degradation, reliable measurement of CO₂ emissions is essential. In the recent past, most researchers have utilized production-based emissions in their studies, ignoring the important role of consumption-based emissions in environmental degradation. Therefore, the present research examines the drivers of consumption-based CO₂ emissions in SAARC nations over the period 1990 to 2018. By employing traditional and second-generation panel cointegration methodologies, the study, more specifically, explores the link between consumption-based CO₂ emissions and its four macroeconomic determinates, namely, GDP growth, energy consumption, FDI, and trade openness (measured by Composite Trade Share Index). The study also applies the FMLOS and DOLS techniques for calculating the long-run elasticities of regressors with respect to the explained variable. The results establish a cointegration relationship between the variables and validate the “EKC hypothesis” for the SAARC region. It is also found that in the long run, as expected, energy consumption enhances the consumption-based CO₂ emissions while FDI and trade openness improve the environmental quality by plummeting emissions. Most importantly, the study rejects the “pollution-haven hypothesis” for the SAARC region based on the negative and statistically significant coefficient of FDI. Lastly, based on the results, some policies are recommended for the abatement of environmental degradation in SAARC countries. As the SAARC nations rely heavily on fossil-based energy, it is suggestive for these economies to enhance the level of energy efficiency and augment the share of renewable energy sources in the energy-mix. Furthermore, the policy-designers in this region should encourage trade openness and liberalize inward FDI for containing consumption-based emissions.

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Introduction

With the growing impetus on growth augmenting policy initiatives involving rapid industrialization and urban infrastructure development, pollution as a negative externality continues to pose threat to environmental sustainability. This phenomenon is more pronounced especially across the emerging market economies. Recent studies show that urbanisation in emerging nations results in increased energy usage and increased CO₂ emissions (He et al. 2017; Ozatac et al. 2017).

For the regional blocks like SAARC, the growth in demographic pressure over a decade (2001-2011) was as rapid as countries witnessing population increased by 130 million, more than Japan’s total population (Ellis and Roberts, 2018). South Asian Economies rely heavily on the fossil fuels to meet their energy demand, resulting in greenhouse emissions, pollution, overall holding serious implications for the environmental sustainability and health of the population (Shi, 2003; Wijayatunga and Fernando, 2013).

Given this as a negative externality for the entire planet; hence collective efforts to cater the emerging threats is required (Jebil *et al.*, 2016). There have been continuous efforts at the global front in terms of establishing various institutions with specific focus on effectively assessing risks, devising solutions to dealing with climate-related risks. There have been a series of conventions and meetings year on year by these international institutions. The

most recent in line with this will be United Nations Climate Change Conference (COP26), 2021 in Italy, which stresses four key goals, i.e., a) securing global net zero and keep 1.5 degrees within reach, b) adopt to protect communities and natural habitats c) Mobilize Finance d) delivering global collaboration to tackle global warming. Before that, in 2018, the United Nations Climate Change Conference (COP24) was held in Poland. It stressed the importance of putting the Paris Agreement into action (COP15). Furthermore, the COP24 reemphasized the importance of keeping CO₂ emissions below the Kyoto Protocol agreement (Nicholas Apergis and Danuletiu, 2014).

The evidence on the relationship between renewable energy usage and economic growth variables with CO₂ emissions has been well documented across different geographies and time periods all over world (Mohsin et al. 2018; Sun et al. 2019). Among key macroeconomic variables, trade openness has been found to be significantly explaining the cause of CO₂ emissions in various studies (Adams and Klobodu 2017; Ertugrul et al. 2016). Ertugrul et al. (2016) have argued in explaining the pollution haven hypothesis (PHH) that with rising incomes, the clean environment is also demanding, which leads to the relocation in countries with less environmental concern for high CO₂ emission industries (KuklaGryz, 2009) and where income is selected for the trade between income and pollution. This was also verified in a research conducted by Gökmenolu and Taspinar (2016), which examined the instance of Turkey. While trade openness is important in determining CO₂ emissions, the findings from the existing literature are contradictory in nature (Dogan 2015; Nasir & Rehman 2011; Shahbaz et al. 2013). Especially for the SAARC region, it remains as a testable proposition. SAARC region holds a significant position being the most populous region comprising more than one-fifth of the world population and the world's fastest-growing region (WDI, 2020). Better prospects of growth imply a surge in energy demand which primarily is fulfilled via non-renewable resources. Further, there has been a shift in the biodiversity of the region due to frequent episodes of extreme weather events. Such events are projected to be more frequent and hence an issue of policy concern for the region.

To achieve sustainable development goals 2030, sustainable consumption with sustainable production cycles are the key factors. Production-based carbon emissions have been the subject of extensive research, with a significant amount of effort devoted to understanding their consequences. Very few studies (Knight & Schor, 2014; Adebayo, 2021) have considered consumption-based carbon emissions to assess environmental degradation. The consumption-based approach towards carbon emissions is distinctive because it considers the global supply chain that contributes to emission generation and distinguishes between emissions generated in one country from those used in another (Khan et al. 2020; Safi et al., 2021). Therefore, the current study adds to the knowledge base through the proxy to environmental degradation of consumption-based carbon emissions (CCO₂). In selected SAARC countries, trends of CCO₂ are presented in Figure 1. During the sample period it displays an increasing trend. The validity of the Environmental Kuznets Curve (EKC) and the PHH are investigated in this paper. In addition, the study also examines the impact of FDI, trade openness, energy consumption, and economic growth on CCO₂ emissions in SAARC countries during 1990–2019.

The earlier studies in the literature have used traditional measures to estimate trade openness. Trade openness in the estimation model is considered as the proxy for technological progress. According to Gozgor (2017) and Waugh & Ravikumar (2016), the trade potential index (TPI) can be used as a proxy for technological progress. On the other hand, an open economy is defined by Squalli and Wilson (2011) as one that has a relatively high proportion of trade in total economic activity and significant engagement and interconnectivity with the rest of

the world. These two dimensions are significant because they are concerned with actual trade flows rather than anticipated trade flows. With this backdrop, the present paper analyzes the determinants of CCO₂ emissions in SAARC countries during 1991–2019. In a number of ways, this work contributes to the literature. Firstly, CCO₂ emissions are employed as a proxy for environmental deterioration rather than ecological and production-based CO₂ emissions. Secondly, trade openness approach of Squalli and Wilson (2011) is used instead of traditional trade to GDP ratio. Lastly, this will be the first CCO₂ emissions study in SAARC countries.

Insert {Figure 1}

Review of the Literature

Linkage between Economic Growth and CO₂ Emissions

The EKC theory asserts that environmental degradation grows with output in the early phases of economic growth, but afterwards diminishes. The EKC hypothesis is explained by three distinct mediums: scale, composition, and method influences (Grossman and Krueger, 1995; Antweiler, 2001). According to the scale effect, emissions tend to rise due to greater economic activities that are harmful to the environment. As industrial technology gets more environmentally friendly and efficient, the technique effect tends to reduce emissions. The composition effect states that as an economy's industries get cleaner, emissions decrease. The EKC hypothesis's importance and stability in explaining the relationship between production and pollution motivated a quest for both empirical and theoretical explanations. Apergis (2016) analysed data from fifteen countries from 1960 to 2013 to assess the validity of the EKC hypothesis using both panel and time series cointegration methods. They identified an inverse U-shape connection between CO₂ emissions and economic growth in twelve of the fifteen countries investigated. The remaining three countries appeared to support the EKC theory, but only in particular quantiles. Similarly, studies by Ang (2007), Halicioglu (2009), Nasir and Rehman (2011), Shahbaz et al. (2015), Tutulmaz (2015), Ahmad et al. (2016), Alam et al. (2016), Dong et al. (2016), Chakravarty and Mandal (2016), Sapkota and Bastola (2017), Rehman and Rashid (2017), Gill et al. (2018), Bekun et al. (2019), Sharif et al. (2019), Pan et al. (2019), Ahmad and Le (2021) confirmed the validity of EKC hypothesis. Whereas studies by Zoundi (2017), Aye and Edoja (2017), Neve and Hamaide (2017), Lotz and Dogan (2018) concluded that there is no association between output and pollutants.

Insert {Table 1}

Linkage between Energy Consumption and CO₂ Emissions

The second strand investigates the link between energy consumption (EC) and carbon dioxide emissions (CO₂). Ito (2017), for example, obtained data for 42 industrialized countries from 2002 to 2011, using the GMM and PMG models, and discovered an inverse link between EC and carbon emissions. Cai et al. (2018) examined the link between EC and CO₂ emissions for G7 countries from 1965 to 2015 using the bootstrap ARDL bound test, finding unidirectional causality from clean EC to CO₂ emissions. Chen et al. (2020) observed a statistically insignificant influence of EC on CO₂ emissions for 36 OECD nations between 1970 and 2016. They employed the Random Effects Model (REM) and panel quantile regression using the fixed effects (FE) methods of moments. Other studies, such as Zhang (2011), Alam et al. (2011), Ocal and Aslan (2013), Magazzino (2016), Banday and Aneja (2019), and Ocal and Aslan (2013), investigated the causal relationship between EC and CO₂ emissions and came up with mixed results.

Insert {Table 2}

Linkage between FDI and CO2 Emissions

The third focuses on the relationships between FDI and CO₂. The Pollution Haven Hypothesis (PHH) was explored for panel data of 28 Chinese provinces by Ahmad et al. (2021), who discovered the existence of PHH in seven provinces with varying levels of development. Thai- Ha et al. (2020) used three composite financial inclusion measures to examine the relationship between FDI and CO₂ emissions for a sample of 21 Asian countries from 2004 to 2014. The study demonstrates PHH's validity and revealed that greater financial inclusion contributed to greater CO₂ emissions. PHH is also supported by research (Phuc Nguyen et al., 2020; Muhammad et al., 2021). Mujtaba and Jena (2021) analyses the asymmetric effects of FDI on CO₂ emissions in India. Their study support the PHH hypothesis. Kim (2019) employed VECM model to assess the causative link for 57 developing countries from 1980 to 2013, finding no direct short-run causality between FDI and CO₂ emissions, rejecting the prevalence of PHH in these countries. He et al. (2020) adopted the Bootstrap Autoregressive Distributed Lagged Model (ARDL) approach on a panel of BRICS countries. They observed a poor association between FDI and carbon emissions.

Insert {Table 3}

Linkage between Trade Openness and CO2 Emissions

The final section is concerned with the relationship between trade openness (TO) and CO₂ emissions. Zhang et al. (2017) studied a panel of recently industrialized nations (NICs-10) from 1971 to 2013 and observed a robust and negative association with TO and CO₂ emissions. Some studies, such as (Sharma, 2011; Sarkodie et al., 2019; Ragoubi and Mighri, 2020), studied the relationship and noticed that TO seems to have a detrimental impact on CO₂ emissions. In contrast, Bhat and Mishra (2018) looked examined the long- and short-term relationships between CO₂ emissions and their primary determinants in India from 1971 to 2013. They came to the conclusion that TO tends to enhance CO₂ emissions. Trade openness appeared to have a considerable impact on CO₂ emissions, according to Phuc et al. (2020) and Chen et al. (2021). Rasoulinezhad & Saboori (2018) used Composite Trade Index (CTI) to measure trade openness (TO) as proxy and found unidirectional short-run panel causality effect of trade openness on CO₂ emissions. Kasman and Duman (2015) discovered a unidirectional short-run link between TO and CO₂ emissions in their study. In contrast, Jamel and Maktouf (2017) and Rahman et al. (2020) discovered a bidirectional causal relationship between TO and CO₂ emissions. Saidi and Mbarek (2017) used time series data from 1990 to 2013 to examine the relationship for emerging economies and found that TO was an insignificant determinant of CO₂ emissions.

However, only a few studies have been conducted for the SAARC region. Rehman and Rashid (2017) have used FMOLS and DOLS approaches to detect the presence of EKC and PHH hypotheses in SAARC countries. The authors examined the impact of energy consumption, GDP, and population growth, as well as CO₂ emissions, on environmental degradation, and predicted bidirectional causality between CO₂ emissions and EG. Afridi et al. (2019) analyzed SAARC countries for panel data from 1980- 2016. The authors advocated the EKC hypothesis and obtained N shaped EKC by incorporating a cubic function. The results reported a negative relationship between CO₂ and TO and a positive with the rest of the variables. Using panel data from 1986 to 2014, Waqih et al. (2019) examined the relationship between foreign direct investment and carbon dioxide for SAARC countries. The study implemented panel ARDL and FMOLS and validated the PHH and EKC hypotheses in the short run and the absence of PHH in the long run. Dar and Asif (2019) investigated the impact of renewable energy consumption, trade liberalisation, real income, agricultural contribution, and urbanisation on carbon emissions in

five SAARC countries from 1990 to 2013. The study used Pedroni and Kao cointegration techniques as well as Granger causality tests and found no evidence of PHH. Khalid et al. (2021) investigated the impact of trade openness, financial development, economic growth, and primary and renewable energy utilisation on environmental quality in SAARC countries using panel data from 1990 to 2017. In the case of SAARC countries, the authors predicted that financial development would be fragile.

Insert {Table 4}

Data and Methodology

Data and Model Specification

This study analyses annual data from 1990 to 2018 to estimate the major determinants of CCO2 emissions in the SAARC countries. Bangladesh, Nepal, India, Pakistan, and Sri Lanka are sample SAARC countries. These countries have been chosen solely on the basis of the availability of data in each of them. CCO2 emissions are employed as a proxy for environmental degradation in this study as the dependent variable. CCO2 emissions have a significant advantage over production-based CO2 emissions. In recent years, many emerging economies have seen a substantial reduction in production-based CO2 emissions due to sustained economic growth (Iqbal et al., 2021). According to Davis and Caldeira (2010), rather than actual reductions in carbon emissions, reported reductions in production-based CO2 emissions are mainly the result of PHH. Therefore, consumption-based CO2 emissions plays a critical role in ensuring a fair distribution of responsibility among nations. Moreover, this study used economic growth, energy consumption, FDI inflows, and trade openness as the explanatory variables. These variables are selected on basis of review of literature and their significance with respect to environmental degradation in SAARC countries. The study utilized Squalli and Wilson's (2011) Composite Trade Share (CTS) approach rather than trade percent GDP to estimate trade openness in the presence of technological progress. The definition of trade openness and how it is measured has been ambiguous (Ngouhouo et al., 2021; Udeagha and Ngépah, 2021). Trade openness is traditionally assessed by using the trade to GDP ratio (Kumar et al., 2021). Traditional approaches to trade openness fail to fully influence economic growth as they ignore the country's openness to world trade. Because it incentivizes larger economies by labelling and portraying them as closed economies as a consequence of their higher GDP (Squalli and Wilson, 2011). It is calculated using the formula below.

$$CTS_i = \frac{(X+M)_i}{1/n \sum_{j=1}^n (X+M)_j} \cdot \frac{(X+M)_i}{GDP_i} \quad (1)$$

Where X is the export, M is the import, and GDP is the country's Gross Domestic Product. Detailed explanations of the variables and data sources are provided in Table 5.

Insert {Table 5}

Following a review of the literature, we hypothesized that GDP, EC, FDI, and TO all had an impact on CCO2 emissions and developed the following empirical model:

$$CCO2_{it} = f(Y, EC, FDI, TO) \quad (2)$$

where i and t denote the country and year, respectively. The model also adds the square of per capita GDP to assess the EKC hypothesis's validity for sample SAARC countries. The model is redefined by taking natural logarithms of all these variables to deal with heteroskedasticity as follows in equation (3):

$$\ln CCO2_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \beta_4 \ln FDI_{it} + \beta_5 \ln TO_{it} + \varepsilon_{it}$$

(3)

where β s denotes the elasticities to be evaluated and ε denotes the error term that accounts for random effects.

Cross-Sectional Dependence, Panel Unit Root Tests and Panel Cointegration Tests

We begin by employing cross-sectional dependence (CSD) tests. In addition to socio-economic and cultural similarities, the selected SAARC nations have various bilateral and multilateral ties in commercial and scientific fields. Moreover, some of the SAARC countries share a common border and may affect the trans-border pollution effect. As a result, the inter-dependence among them is high. We check the cross-sectional dependence among sample countries by employing CD and Scaled LM tests proposed by Pesaran (2004) as well as the Breusch-Pagan LM test. The equation for the CD test is presented in equation (4).

$$CSD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N P'_{ij} \right) \Rightarrow N(0,1) \quad (4)$$

Where T denotes the time period, N is the sample size and P_{ij} is the sample estimate of correlation errors for each cross-section of country i and j defined as follows in Equation 5.

T signifies the time, N denotes the sample size, and P_{ij} denotes the correlation error sample estimate for each cross-section of the country i and j as specified in Equation 5.

$$P'_{ij} = \frac{\sum_{t=1}^T u_{it}u_{jt}}{(\sum_{t=1}^T u_{it}^2)^{1/2} (\sum_{t=1}^T u_{jt}^2)^{1/2}} \quad (5)$$

The stationarity of target variables is checked prior to the empirical estimation of the panel model because all of the panel cointegration tests are based on a presupposition that the variables of order I(0), I(1) or mix of both are integrated and no variables of order I(2) or beyond are integrated. To begin, the study uses four well-known first-generation panel unit root tests: Fisher ADF, Fisher PP, Im, Pesaran, and Shin (IPS) and Levin, Lin, and Chu (LLC). The stationarity properties have been investigated separately with the only intercept and with both trend and intercept. In contrast to the alternative hypothesis of no unit root, the null hypothesis of the unit root test confirms the presence of a unit root in the series.

The first-generation unit root tests may give biased results when there is heterogeneity and cross-sectional dependence. As a result, two second-generation panel unit root tests: cross-section ADF (CADF) and cross-sectionally augmented IPS (CIPS) are used. Both tests were developed by Pesaran (2007). As a consequence, two root unit tests of Pesaran (2007) of second-generation are being performed: ADF-cross section (CADF) and IPS-cross-sectional increment (CIPS).

After validating that all of the variables in this study are I(0) and I(1), the study applies four types of panel cointegration tests to determine the existence of a long-run linkage between the variables: Pedroni (1999, 2000), Kao (1999), and Johansen Fisher (1999). Finally, the study use the Westerlund (2007) cointegration test to resolve cross-sectional dependence among selected nations. This is an error correction-based test that is resilient to cross-sectional dependence.

FMOLS, DOLS and DH Panel Model

After determining the long-run relationship, we intend to compute the long-run elasticities of all explanatory variables included in our model with respect to the explained variable. For this, we have employed panel FMOLS

and DOLS methods suggested by Pedroni (2001, 2004). These methods can be expressed as presented in equation (9) and equation (10):

$$\hat{\beta}_{FMOLS}^* = N^{-1} \sum_{n=1}^N \hat{\beta}_{FMOLS}^* \cdot n \quad (9)$$

$$\hat{\beta}_{DOLS}^* = N^{-1} \sum_{n=1}^N \hat{\beta}_{DOLS}^* \cdot n \quad (10)$$

The heterogeneous panel causality test of Dumitrescu and Hurlin (DH) (2012) is utilised for determining the causal link of the panel variables with reference to CCO2 emissions after measuring the elasticities of Y, squared Y, C, FDI and TO. A causal relationship between the variables is asserted by the null hypothesis versus the alternative hypothesis, which says that there is a causal linkage among the variables, in DH test.

Empirical Results and Discussions

Table 6 summarises descriptive statistics for the variables under discussion. The lower part of Table 6 shows the correlation matrices among the variables. The correlation analysis manifests that Y, EC, FDI, and TO are significantly and positively correlated with CCO2 emissions. Similarly, EC, FDI, and TO have a significant and positive correlation with Y. TO is also positively correlated with FDI. Table 1 also indicates a strong correlation between the explanatory variables, which implies the likelihood of multicollinearity. The observed high collinearity is probably due to the inclusion of the square term of Y so as to validate the “EKC hypothesis”. Allison (2012) and Waqih et al. (2019) argued that this term neither affects standard error nor probability of the model; thus, it has no effects on results. Nevertheless, to safeguard our panel model from the potential multicollinearity, we apply a VIF test for explanatory variables (Table 16). The results show that the mean VIF value is 1.67 and the individual VIF values for lnY, lnEC, lnFDI, and lnTO are 2.01, 1.75, 1.84 and 1.09 respectively are well below the critical value. Results for the CSD test are presented in Table 7. Following our findings, we conclude that cross-sectional dependency exists in our sample of five SAARC nations, rejecting the null hypothesis of "no cross-sectional dependence."

Insert {Table 6}

Insert {Table 7}

Table 8 and Table 9 show the unit root tests of first-generation. All variables, with the exception of lnFDI, have a unit root at a level, and there is no unit root at the first difference, according to the findings of these tests. Only lnFDI is found stationary at both level and first difference.

Insert {Table 8}

Insert {Table 9}

The results for CADF and CIPS are presented in Table 10. The results of CADF show that lnCCO2, lnY, lnY2 and lnTO are stationary at first difference, while lnFDI is stationary at both level and first difference. CIPS results indicate that all panel variables have a unit root at the level, but they become stationary when the first difference is taken. In conclusion, all of the variables are I(0) and I(1) in both unit root tests of first and second generation.

Insert {Table 10}

The results of the Pedroni cointegration tests are displayed in Table 11. Four out of seven statistics (two within dimension and two between dimensions) reject the “null hypothesis of no cointegration” indicating that Y, square of Y, EC, FDI and TO have a long-run association with CCO2 emissions in our sample of five SAARC countries.

The Kao cointegration test is tabulated in Table 12. The results of this test corroborate Pedroni cointegration's conclusions by implying that the variables are in long-run equilibrium. Table 13 shows the results of Johansen Fisher's cointegration test. The reported trace and maximum-eigenvalue statistics show the presence of a maximum of six cointegration equations. This further strengthens the case for the long-run cointegration of our chosen panel variables. Table 14 displays the results of the Westerlund cointegration test. According to the results shown in Table 8, 3 out of 4 statistics refute the null hypothesis of no cointegration, which has been accepted as true, at a level of significance of less than 5%. In summary, we conclude from all four tests of co-integration test that there is strong empirical evidence that the target variables have a long-running association in the countries of SAARC throughout the period 1990 to 2018.

Insert {Table 11}

Insert {Table 12}

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Insert {Table 14}

Finally, the long-run elasticities of all explanatory variables using FMOLS and DOLS methods are summarized in Table 15. In line with the "EKC hypothesis," which stipulates that per capita GDP and its square term have positive and negative coefficients, respectively, and that both are statistically significant at the one percent level. So, the results of FMOLS and DOLS are consistent with this hypothesis. According to the FMOLS model, when economic growth increases by 1%, CCO2 emissions will rise by 0.334% but when square of economic grows by 1%, CCO2 emissions will fall by 0.334%. Additionally, according to the DOLS approach, every one percent rise in economic growth is accompanied by an increase in CCO2 emissions of 3.334 percent, and every one percent increase in the squared of economic growth generates a decrease in CCO2 emissions of 0.195 percent. These findings regarding the existence of the "EKC hypothesis" serve to corroborate further the findings of Saboori and Sulaiman (2013), Farhani and Shahbaz (2014), Kasman and Duman (2015), Shahbaz et al. (2016), Dogan and Seker (2016), and Pablo-Romero *et al.* (2017) in regards to the ASEAN countries, MENA region, African countries, new EU members, EU 27 countries, and OECD countries.

Insert {Table 15}

Insert {Table 16}

Insert {Table 17}

The DOLS technique uncovers a positive and highly significant link between energy usage and CCO2 emissions in SAARC countries. When energy consumption rises by 1%, CO2 emissions increase by more than unity (1.135%). This finding is consistent with previous findings by Aroui et al. (2012) for MENA countries, Ozturk and Acaravci (2013) for Turkey, Shahbaz et al. (2015) for a sample of high, middle, and low-income countries, Tang and Tan (2015) for Vietnam and Baek (2015) for Arctic countries.

Contrary to the "pollution haven hypothesis" FMOLS technique indicates that inward FDI significantly diminishes CCO2 emissions in SAARC countries. To be more specific, a rise of one percent in foreign direct investment (FDI) inflows reduces environmental pollution (CCO2 emissions) by 0.067 percent. This positive effect of FDI experienced by SAARC countries may be attributed to the adoption of modern technology and approaches designed for improving environmental quality. This empirical finding is consistent with Zhu et al. (2016) for ASEAN-5 countries and Waqih et al. (2019) for SAARC countries. However, this outcome is contrary to those reported by Baek and Koo (2008), Chandran and Tang (2013), Shahbaz et al. (2018) and, Khan and

Ozturk (2019). To summarize this result, we can conclude that the “pollution haven hypothesis” is rejected in SAARC countries favoring the “pollution halo hypothesis” from 1990 to 2018.

Trade openness is found to boost the environmental quality in SAARC countries by plummeting CCO₂ emissions. The coefficients of trade openness obtained from FMOLS and DOLS are -0.025 and -0.008, respectively. These findings are the same as Dogan and Seker (2016) for 23 top renewable energy-using nations, Shahbaz et al. (2013) for Indonesia, and Zhang et al. (2017) for 10 newly industrialized countries, but differ from Shahbaz et al. (2016) for BRICS countries. According to Zhang et al. (2017), trade openness can encourage the transfer of innovative technologies from industrialised to developing economies, reducing CO₂ emissions. The findings of the DH causality test are presented in Table 17. The findings support the unidirectional causality that runs from economic growth to CCO₂ emissions and the unidirectional causality that runs from squared economic growth to CCO₂ emissions. These outcomes align with (Dogan and Seker, 2016). The results also reveal the evidence of unidirectional causality from economic growth to energy consumption, squared economic growth to energy consumption and trade openness to energy consumption.

Conclusion and Policy Recommendations

This research is an empirical attempt to determine the key drivers of consumption-based carbon dioxide emissions in SAARC nation for a time span of 1990 to 2018. We investigate the effects of economic growth, energy consumption, trade openness, and FDI on consumption based CO₂ emissions. Unlike most previous researches, our study utilizes consumption-based CO₂ emissions as a proxy for environmental deterioration. Further, instead of considering nominal trade openness or trade potential index as a proxy of trade openness, this paper considers Composite Trade Share for the same. The study employs both the first and second-generation unit root tests, revealing all the variables are stationary either at level or at first difference. After confirming all the variables under the present research are I(0) and I(1), we performed first and second generation cointegration tests. The findings of these cointegration tests show that the target variables have a strong empirical evidence of a long-run equilibrium relationship. Both FMOLS and DOLS results confirm the "EKC hypothesis" that economic growth and its square component have positive and negative coefficients, respectively. Along with economic growth, energy usage, FDI, and trade openness are also statistically significant. The DOLS approach demonstrates a positive and statistically significant link between energy usage and CCO₂. The negative elasticity of FDI indicates that the “pollution haven hypothesis” is rejected in SAARC countries favoring the “pollution halo hypothesis” over the period 1990 to 2018. This implies that an inward FDI flow significantly diminishes CO₂ emissions in SAARC countries. Trade openness is also found to improve the environmental quality in SAARC countries by reducing CO₂ emissions. DH causality test results support the unidirectional causality running from economic growth to CCO₂ emissions and from squared economic growth to CCO₂ emissions. The results also reveal the evidence of unidirectional causality from economic growth to energy consumption, squared economic growth to energy consumption, and trade openness to energy consumption.

Some of the policy recommendations emanating from this study are:

The findings show that in the SAARC area, trade openness and FDI have a negative impact on carbon dioxide emissions. At the same time, GDP and energy consumption are the primary drivers of environmental degradation.

1. The result manifests that SAARC nations are now using a high level of energy, which is causing environmental degradation. Therefore, it is suggestive for these economies to enhance the level of energy

- efficiency and augment the share of renewable energy sources in the energy mix. Additionally, they should pay more attention to environmental protection by implementing policies and designing action agendas.
2. The importance of the scale effect in economic activity must be addressed, and SAARC countries should invest in new technologies that are both environmentally benign and efficient.
 3. The region must also concentrate on strategies to reduce emissions by fostering industries that use green and cleaner energy sources. Aside from that, the area should focus on green projects in a shared forum and use advanced carbon-reduction mechanisms (Cap & Trade, Carbon Permits) to reduce emissions.
 4. SAARC countries' energy usage is heavily reliant on nonrenewable sources. Therefore, alternative energy resources should be discovered for both economic growth and environmental protection. Furthermore, nonrenewable resources must be used wisely and effectively. To reproduce the intended results, policies must be developed in a shared forum.
 5. National policies should also be designed to combat environmental degradation like creating awareness and disseminating information regarding harmful effects of rising carbon emissions and resulting environmental unsustainability.

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List of Tables

Table 1. An overview of the Literature on Environmental degradation Economic and Growth

S. No.	Authors	Methodology	Country	Time Period	Key Findings
1.	Apergies (2016)	Panel ARDL	15 Countries	1960- 2013	EKC holds in 12 out of the 15 countries based on the quantile cointegration approach.
2.	Chakravarty and Mandal (2016)	Fixed Effects and GMM	BRICS countries	1997- 2011	EKC holds.
3.	Alam et al. (2016)	ARDL model	Brazil, China, Indonesia, and India	1970- 2012	EKC holds in all four countries.
4.	Zoundi (2017)	Panel Cointegration approach, DOLS, GMM, Pooled Mean Group	25 African countries	1980-2012	EKC does not hold.
5.	Aye and Edoja (2017)	Dynamic panel threshold model	31 developing countries	1971- 2013	EKC doesn't hold.
6.	Rehman and Rashid (2017)	FMOLS and DOLS and Panel Cointegration	Emerging and frontier Asian (EFA) markets	1960-2015	EKC holds, bidirectional causality between CO ₂ and EG
7.	Lotz and Dogan (2018)	Panel DOLS model	10 Sub- Saharan African countries	1980- 2011	EKC doesn't hold.
8.	Bekun et al (2019)	PMG- ARDL	16 EU countries	1996- 2014	EKC holds
9.	Sharif et al (2019)	FMOLS	74 countries	1990- 2015	EKC holds.
10.	Pan et al. (2019)	Symbolic regression method	34 OECD countries	1995- 2014	EKC holds in 17 countries.
11.	Seetanah et al. (2019)	Panel VAR model	12 small island developing countries	2000- 2016	EKC doesn't hold in SR but in LR
12.	Ahmad and Le (2021)	CUP-FM panel model	ASEAN countries	1996-2017	EKC holds.

Table 2. An overview of the Literature on Environmental degradation and Energy Consumption

S. No.	Authors	Methodology	Country	Time Period	Key Findings
1.	Ito (2017)	GMM and PMG model	42 developed countries	2002- 2011	Inverse relationship between EC and CO ₂
2.	Cai et al. (2018)	Bootstrap ARDL	G7 countries	1965- 2015	Unidirectional causality from EC to CO ₂ for US.
3.	Banday and Aneja (2019)	Pooled Mean Group ARDL	G7 countries	1971- 2014	LR relationship between EC and CO ₂
4.	Wang and Dong (2019)	Augmented Mean Group	14 Sub- Saharan African countries	1990- 2014	Bidirectional LR causality between EC and CO ₂
5.	Chen et al. (2020)	Panel quantile regression approach	36 OECD countries	1970- 2016	EC found statistically insignificant
6.	Magazzino et al. (2021)	Wavelet approach	Italy	Several time scales	Bidirectional causality at lower scales
7.	Mujtaba et al. (2020)	FMOLS, DOLS	25 upper middle-income countries	1985-2014	positive relationship between EC and CO ₂

Table 3. An overview of the Literature on Environmental degradation and Foreign Direct Investment

S. No.	Authors	Methodology	Country	Time Period	Key Findings
1.	Kim (2019)	VECM	57 Developing Countries	1980- 2013	PHH does not hold in short run.
2.	He et al. (2020)	Bootstrap ARDL	BRICS	1970- 2018	PHH does not hold.
3.	Thai-Ha et al. (2020)	Pooled OLS, Fixed effects and GLS.	21 Asian countries	2004- 2014	PHH holds.
4.	Phuc Nguyen et al. (2020)	STIRPAT model, Pooled OLS and FGLS	33 Emerging economies	1996- 2014	PHH holds
5.	Muhammad et al. (2020)	STIRPAT model, DOLS	13 Muslim countries	2002- 2014	PHH holds
6.	Mujtaba and Jena (2021)	NARDL	India	1986-2014	PHH holds
7.	Ahmad et al. (2021)	DCCEMG method	28 Chinese provinces	1998- 2016	PHH holds

711 **Table 4.** An overview of the Literature on Environmental degradation and Trade Openness

S. No.	Authors	Methodology	Country	Time Period	Key Findings
1.	Saidi and Mbarek (2017)	GMM	19 Emerging economies	1990- 2013	TO is insignificant.
2.	Zhang et al. (2017)	Panel OLS, FMOLS, DOLS	Newly industrialized countries (NICs- 10)	1971- 2013	TO found significant and negative.
3.	Jamel and Maktouf (2017)	Cobb- Douglas production function	40 European countries	1985- 2014	Significant and Bidirectional causal linkage.
4.	Bhat and Mishra (2018)	ARDL bounds test	India	1971- 2013	TO is positively significant
5.	Rasoulinezhad & Saboori (2018)	DOLS and FMOLS	Commonwealth of Independent States (CIS) region	1992- 2015	Unidirectional SR causality from TO to CO ₂ emissions
6.	Sarkodie et al. (2019)	ARDL, FMOLS	14 African countries	1990- 2013	TO found significant and negative.
7.	Ragoubi and Mighri (2020)	QML, GMM and MCMC	54 Middle- Income countries	1996- 2013	TO found significant and negative.
8.	Rahman et al. (2020)	FMOLS, DOLS, and GMM	Five South Asian countries	1990- 2017	Significant and Bidirectional causal linkage.
9.	Phuc et al. (2020)	STIPPAT model, Pooled OLS, FGLS	33 Emerging economies	1996- 2014	TO is positively significant
10.	Chen et al. (2021)	Panel quantile regression approach	64 Countries along the Belt & Road	2001- 2019	TO is positively significant
11.	Khalid et al. (2021)	AMC, ECM, and DH panel non-causality tests	SAARC countries	1990- 2017	TO is positively significant in Nepal.

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713 **Table 5.** Data Source and Description of the Variables

Variable	Description	Unit	Data Source
lnCCO ₂	Consumption-based CO2 emissions per person	Metric ton	World Development Indicators
lnY	Gross Domestic Product (GDP) per capita	Constant 2010 prices	World Development Indicators
lnY ²	Square of GDP	Constant 2010 prices	World Development Indicators
lnEC	Energy consumption per capita	kg of oil equivalent	World Development Indicators
lnFDI	Foreign Direct Investment net inflows	% of GDP	World Development Indicators
lnTO	Trade Openness	current US \$	Calculated using Composite Trade Share

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715 **Table 6.** Descriptive Statistics and Correlation Matrix

	lnCCO2	lnY	lnY2	lnEC	lnFDI	lnTO
Mean	-0.586	6.821	46.868	5.874	-0.586	14.125
Median	-0.337	6.717	45.122	6.004	-0.217	14.232
Maximum	0.554	8.281	68.567	6.633	1.300	22.275
Minimum	-2.746	5.870	34.457	4.778	-5.406	7.810
Std. Dev.	0.749	0.584	8.191	0.427	1.312	3.424
Skewness	-0.760	0.613	0.790	-1.045	-1.647	0.280
Kurtosis	2.760	2.791	3.082	3.374	5.828	2.537
Jarque-Bera	14.315	9.342	15.140	27.235	110.741	3.191
Probability	0.001	0.009	0.001	0.000	0.000	0.203
Observations	145	145	145	145	141	145
Correlation Matrix						
lnCCO2	1.000					
lnY	0.789***	1.000				
lnY2	0.769***	0.999***	1.000			
lnEC	0.694***	0.610***	0.600***	1.000		
lnFDI	0.656***	0.636***	0.616***	0.550***	1.000	
lnTO	0.505**	0.195**	0.174**	0.236**	0.273***	1.000

716 Note. “***” and “**” indicate the level of significance at 1% and 5%, respectively.

717 **Table 7.** Cross-Sectional Dependence Test

Test	Statistic	Prob.
Breusch-Pagan LM	54.324***	0.000
Pesaran scaled LM	9.911***	0.000
Pesaran CD	4.338***	0.000

718 Note. “***” indicates the level of significance at 1%.

719 **Table 8.** First Generation Panel Unit Root Tests (with intercept)

Variable	Fisher-ADF		Fisher-PP		IPS		LLC	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
lnCCO2	2.488 (0.991)	91.587 (0.000)	2.190 (0.995)	110.290 (0.000)	2.769 (0.997)	-10.011 (0.000)	0.487 (0.687)	-10.774 (0.000)
lnY	0.092 (1.000)	48.628 (0.000)	0.115 (1.000)	49.118 (0.000)	7.937 (1.000)	-5.367 (0.000)	5.768 (1.000)	-5.288 (0.000)
lnY2	0.037 (1.000)	43.107 (0.000)	0.056 (1.000)	42.927 (0.000)	8.748 (1.000)	-4.654 (0.000)	6.771 (1.000)	-4.325 (0.000)
lnEC	4.022 (0.946)	73.008 (0.000)	3.620 (0.963)	84.192 (0.000)	5.948 (1.000)	-7.972 (0.000)	4.425 (1.000)	-9.252 (0.000)
lnFDI	73.185 (0.000)	87.417 (0.000)	32.001 (0.000)	95.145 (0.000)	-8.015 (0.000)	-9.501 (0.000)	-6.379 (0.000)	-7.621 (0.000)
lnTO	14.701 (0.143)	134.87 (0.000)	14.733 (0.142)	134.80 (0.000)	-1.497 (0.067)	-14.678 (0.000)	-1.186 (0.118)	-17.015 (0.000)

720 Note. P-values are in the parenthesis.

Table 9. First Generation Panel Unit Root Tests (with intercept and trend)

Variable	Fisher-ADF		Fisher-PP		IPS		LLC	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
lnCO2	17.952 (0.056)	88.509 (0.000)	14.084 (0.169)	134.574 (0.000)	-1.622 (0.052)	-10.337 (0.000)	-1.061 (0.145)	-9.967 (0.000)
lnY	8.092 (0.620)	39.055 (0.000)	3.771 (0.957)	88.262 (0.000)	0.905 (0.817)	-4.669 (0.000)	-0.091 (0.464)	-4.816 (0.000)
lnY2	5.716 (0.839)	38.458 (0.000)	2.107 (0.996)	63.649 (0.000)	1.748 (0.960)	-4.596 (0.000)	0.474 (0.682)	-4.424 (0.000)
lnEC	5.916 (0.822)	80.689 (0.000)	6.170 (0.801)	84.595 (0.000)	1.920 (0.973)	-9.711 (0.000)	0.470 (0.681)	-10.718 (0.000)
lnFDI	53.785 (0.000)	67.182 (0.000)	22.909 (0.011)	174.244 (0.000)	-6.260 (0.000)	-7.820 (0.000)	-5.740 (0.000)	-4.384 (0.000)
lnTO	11.891 (0.292)	118.262 (0.000)	11.526 (0.318)	118.521 (0.000)	-0.997 (0.159)	-13.722 (0.000)	-0.902 (0.184)	-15.425 (0.000)

Note. P-values are in the parenthesis.

Table 10. Second Generation Unit Root Tests with Trend and Intercept

Variable	CADF		CIPS	
	I(0)	I(1)	I(0)	I(1)
lnCCO2	-1.843	-3.484***	-2.197	-5.185***
lnY	-2.082	-3.664***	-2.629	-4.534***
lnY2	-1.929	-3.547***	-2.409	-4.405***
lnEC	-0.94	-3.155**	-1.193	-5.537***
lnFDI	-4.607***	-5.14***	-2.948	-5.562***
lnTO	-2.848	-3.922***	-2.973	-5.355***

Note. “***” and “**” indicate the level of significance at 1% and 5%, respectively.

Table 11. Pedroni Cointegration Test

	Statistic	Prob.
Within-dimension (homogenous)		
Panel v-Statistic	1.233	0.109
Panel rho-Statistic	0.932	0.824
Panel PP-Statistic	-3.445***	0.000
Panel ADF-Statistic	-3.821***	0.000
Between-dimension (heterogeneous)		
Group rho-Statistic	1.882	0.970
Group PP-Statistic	-3.188***	0.001
Group ADF-Statistic	-2.467***	0.007

Note. “***” indicates the level of significance at 1%.

Table 12. Kao (1999) Cointegration Test

	t-Statistic	Prob.
ADF	-2.081**	0.019
Residual variance	0.006	
HAC variance	0.007	

Note. “***” indicates the level of significance at 5%.

Table 13. Johansen Fisher Panel Cointegration Test

Tests	Fisher Statistics (from trace test)	Prob.	Fisher Statistics (from max Eigen)	Prob.
None	202.100***	0.000	148.600***	0.000
At most 1	137.400***	0.000	86.070***	0.000
At most 2	104.000***	0.000	59.730***	0.000
At most 3	70.730***	0.000	40.990***	0.000
At most 4	64.750***	0.000	53.060***	0.000
At most 5	23.320***	0.010	23.850***	0.008
At most 6	9.081	0.524	9.081	0.524

Note. “***” indicates the level of significance at 1%.

Table 14. Westerlund (2007) Cointegration Test

Statistic	Value	Z- value	P-value
Gt	-3.193**	1.75	0.04
Ga	-13.506	0.16	0.436
Pt	-7.623***	2.602	0.005
Pa	-16.121**	2.01	0.022

Note. “***” and “**” indicate the level of significance at 1% and 5%, respectively.

Table 15. FMOLS and DOLS Model Results

Variable	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
lnY	5.978***	0.000	3.334***	0.002
	(1.274)		(1.042)	
lnY2	-0.334***	0.000	-0.195***	0.004
	(0.082)		(0.066)	
lnEC	0.119	0.805	1.135***	0.000
	(0.481)		(0.246)	
lnFDI	-0.067**	0.023	-0.011	0.375
	(0.029)		(0.013)	
lnTO	-0.025**	0.033	-0.008*	0.056
	(0.012)		(0.004)	
R-squared	0.947		R-squared	0.984
Adjusted R-squared	0.943		Adjusted R-squared	0.978

Note. “***”, “**”, and “*” indicate the level of significance at 1%, 5%, and 10% respectively. Standard Error (SE) values are in the parenthesis.

Table 16. Variance inflation factor of explanatory variables

Variable	VIF	1/VIF
lnY	2.01	0.497
lnEC	1.75	0.570
lnFDI	1.84	0.543
lnTO	1.09	0.914
Mean VIF	1.67	

740 **Table 17.** D-H Causality Tests

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
lnY does not homogeneously cause lnCO2	5.120***	2.685	0.007
lnCO2 does not homogeneously cause lnY	1.205	-0.914	0.361
lnY2 does not homogeneously cause lnCO2	5.216***	2.773	0.006
lnCO2 does not homogeneously cause lnY2	1.141	-0.973	0.330
lnEC does not homogeneously cause lnCO2	1.330	-0.800	0.424
lnCO2 does not homogeneously cause lnEC	3.956	1.615	0.106
lnFDI does not homogeneously cause lnCO2	2.022	-0.171	0.864
lnCO2 does not homogeneously cause lnFDI	2.419	0.190	0.849
lnTO does not homogeneously cause lnCO2	2.381	0.167	0.868
LNCO2 does not homogeneously cause lnTO	2.985	0.721	0.471
lnY2 does not homogeneously cause lnY	1.554	-0.594	0.553
lnY does not homogeneously cause lnY2	1.537	-0.609	0.542
lnEC does not homogeneously cause lnY	2.015	-0.170	0.865
lnY does not homogeneously cause lnEC	5.636***	3.159	0.002
lnFDI does not homogeneously cause lnY	1.145	-0.970	0.332
lnY does not homogeneously cause lnFDI	3.125	0.833	0.405
lnTO does not homogeneously cause lnY	1.448	-0.691	0.490
lnY does not homogeneously cause lnTO	2.541	0.313	0.754
lnEC does not homogeneously cause lnY2	2.020	-0.165	0.869
lnY2 does not homogeneously cause LNEC	5.469***	3.006	0.003
lnFDI does not homogeneously cause lnY2	1.126	-0.986	0.324
lnY2 does not homogeneously cause lnFDI	3.074	0.787	0.432
lnTO does not homogeneously cause lnY2	1.388	-0.746	0.455
lnY2 does not homogeneously cause lnTO	2.495	0.271	0.786
lnFDI does not homogeneously cause lnEC	1.727	-0.440	0.660
lnEC does not homogeneously cause lnFDI	2.344	0.122	0.903
lnTO does not homogeneously cause lnEC	4.214	1.851	0.064
lnEC does not homogeneously cause lnTO	3.901	1.564	0.118

lnTO does not homogeneously cause lnFDI	2.870	0.601	0.548
lnFDI does not homogeneously cause lnTO	1.740	-0.428	0.669

741 Note. “***” indicates the level of significance at 1%.

Figure 1. Consumption based CO2 Emissions in SAARC Countries during 1990-2018