sustainability

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Consumption-Based CO_2 Emissions on Sustainable Development Goals of SAARC Region

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Citation: Rahman, M.M.; Ahmed, R.; Mashud, A.H.M.; Malik, A.I.; Miah, S.; Abedin, M.Z. Consumption-Based CO_2 Emissions on Sustainable Development Goals of SAARC Region. *Sustainability* **2022**, *14*, 1467. https://doi.org/10.3390/su14031467

Academic Editor: Antonio Caggiano

Received: 28 October 2021
Accepted: 10 January 2022
Published: 27 January 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Consumption-based CO_2 emission (CBE) accounting shows the possibility of global carbon leakage. Very little attention has been paid to the amount of emissions related to the consumption of products and services and their impact on sustainable development goals (SDGs), especially in the SAARC region. This study used a CBE accounting method to measure the CO_2 emissions of five major SAARC member countries. Additionally, a Fully Modified Ordinary Least Square (FMOLS) and a causality model were used to investigate the long-term effects of the CBE and SDG variables between 1972 and 2015. The results showed that household consumption contributed more than 62.39% of CO_2 emissions overall in the SAARC region. India had the highest household emissions, up to 37.27%, and Nepal contributed the lowest, up to 0.61%. The total imported emissions were the greatest in India (16.88 Gt CO_2) and Bangladesh (15.90 Gt CO_2). At the same time, the results for the long-term relationships between the CBEs and SDGs of the SAARC region showed that only the combustible renewables and waste (CRW) variable is significant for most of these countries. The sharing of the responsibility for emissions between suppliers and customers could encourage governments and policymakers to make global climate policy and sustainable development decisions, which are currently stalled by questions over geographical and past emission inequities.

Keywords: carbon intensity; emissions embodied in trade; SDGs; MRIO; environmental sustainability

1. Introduction

Climate change is happening more quickly than expected because carbon dioxide levels are rising globally. It is the most pressing challenge of the 21st century and the most severe threat to sustainable development. Climate change also harms countries' economies and people's lives. The compounding effects of climate change are hastening its progress, allowing limited time to intervene to avoid catastrophic climate change [1]. Atmospheric conditions are unstable, ocean levels are rising, and extreme weather events are becoming increasingly common. Many developing nations have started establishing and implementing national adaptation plans (NAPs) to minimize climate change vulnerability and incorporate climate change adaptation into their national planning. The ability of countries to finance and develop sustainability, primarily among the least developed countries (LDCs) and small island developing states, must be ramped up at a much quicker rate [2]. The two most prominent issues are investing in disaster risk mitigation to resist the effects of climate change and developing policy consistency between climate change and sustainable development goals (SDGs).

The United Nations (UN) established the SDGs, also known as the global goals, in 2015 as a global call to action to eradicate poverty, preserve the environment, and ensure that everyone lives in prosperity and peace by 2030 [3]. Countries need to be considerably more proactive in developing their new nationally determined contributions (NDCs) to meet the 2030 goals. The South Asian Association for Regional Cooperation (SAARC) is one of the world's most dynamic regions and has made rapid progress towards many SDGs. However, the member countries are not all making progress at a similar pace. Development toward the goals has stopped or is heading backward in specific sectors, making it impossible to fulfill them by 2030. Climate change is one of the major concerns for most SAARC member countries as they try to achieve environmental sustainability. For this reason, carbon dioxide (CO_2) emissions must be dropped by 45% by 2030 from the 2010 levels and fall dramatically to attain net-zero emissions by 2050 [4]. The overall emissions must reach a peak as soon as feasible to maintain global warming around 1.5 °C, then drop rapidly.

Global warming insists that developing countries and developed countries work together through a single agreement to solve the emissions problem. There is a drastic need to reduce CO_2 emissions caused by human activities in the SAARC region. Most scientists agree that countries need to take initiative much more quickly to prevent the worst impacts of climate change [5]. Moreover, accounting for CO_2 emissions helps to calculate pollution levels and provide suggestions for changes that need to be made. Consumption-based CO_2 emission (CBE) accounting is the basis for developing a whole new renewable investment market and renewable accounting approach. It is also called the carbon footprint, which is a commercial tool that spreads knowledge about carbon accounting. Knowledge of carbon footprints might be valuable for explaining and mitigating the impacts of climate change. When accounting for CO_2 emissions, one learns the sum of pollution created by a nation. How much carbon is emitted? Who is responsible for these releases? Are there policies or tactics that seem 'green' but could potentially raise carbon emissions? Accounting for CO_2 emissions helps us answer all these questions. Two methods are employed to calculate CO_2 emissions. One considers emissions based on production, and the other emissions based on consumption. CBE accounting encompasses conventional, manufacturing-based inventories of the exports and imports of products and services, including direct or indirect carbon emissions [6].

Over the past three decades, there has been sustained research activity in the field of CBE accounting worldwide [6–8] and at the national level [9–12] with the aim of determining environmental pollution and degradations. The authors of [13–17] used CBE accounting to determine carbon leakage and carbon trade policies. In addition, some studies have been conducted on mitigation pathways for carbon emission reduction and socioeconomic measures for sustainable development [18–21]. No studies have been conducted to calculate consumption-based CO_2 emissions in the SAARC region, and the long-term effects of CO_2 emissions and the progress of the SDGs in this area is still unknown. Therefore, this study aims to measure the CBEs in the SAARC region and examine the long-term effects of the CBEs on the SDGs. To attain this objective, the following research questions were determined and are discussed in this paper:

(1) How will the input–output method that best outlines the variation in CO_2 emissions in SAARC countries use a consumer-based approach?
(2) What effect do the main predictors of sustainable development changes have on consumption-based CO_2 emissions?
(3) Is there any causality between the CBE and SDGs in the SAARC countries?

This research makes a unique contribution to environmental sustainability in the following aspects. Firstly, using a comprehensive Multi-Regional Input–Output (MRIO) model, this study estimates the total CO_2 emissions of SAARC listed countries in the major final demand category such as household, government expenditure, and capital formation.

Secondly, this study compares export and import emissions on the actual economics, GDP, and per capita basis of five SAARC countries. The result shows that each country's difference in consumption, imported, and exported emissions represents a higher and lower carbon emissions ranking. Thirdly, using the FMOLS model and important sustainability indicators, this study measures the long-term cointegration between CBE and SDGs, which helps to identify the expected gap between the environmental degradation and SDGs of 2030 in the SAARC region. Finally, some policies and strategies are recommended for handling the central issue in climate change and SDGs. The finding shows that household consumption (HC) contributed to the highest CO_2 emissions. Overall, imports of emissions from India are nearly three times higher than in Nepal, five times higher than in Pakistan, and nine times higher than in Sri Lanka. CBE and government expenditure (GE) are the most significant variables with a unidirectional relationship between Bangladesh, India, and Sri Lanka for the casualty test. This study also indicates that Bangladesh, India, Nepal, Pakistan, and Sri Lanka are likely to use their renewable energy sources for future sustainable industrial production and use less fossil fuel in the developing sector.

This study is organized as follows: Section 2 reports the existing literature on CBE and sustainable development. Section 3 summarizes the methodology and Section 4 depicts the results and analysis. Section 5 presents the discussion. The conclusion and policy recommendations are provided in the final section.

2. Literature Review

It is essential to be aware of current issues highlighted in the literature. CBE accounting has attracted considerable attention in the literature.

2.1. Consumption-Based CO_2 Emissions

CO_2 has the highest proportion of greenhouse gases (GHGs), owing to its importance in climate policy and rising worries about carbon leakage and competitiveness. One of the most significant worldwide objectives is to track CO_2 emission trends in terms of total and per capita emissions. However, it is also crucial to pay attention to how emissions are estimated, as different accounting methods might provide wildly different results. Most of the previous research on emissions and climate policy relies heavily on data from the production-based accounting (PBA) approach [6,14,15]. However, solely by ignoring the environmental consequences of consumption, PBA presents an imperfect view of the underlying reasons behind these emission shifts and the influence of world trade on emissions. Numerous studies advocate that those national emissions determined by CBE accounting systems should be used in GHG evaluations for development and comparability among nations to solve this challenge [7,8,22,23]. There are numerous studies on global and national level consumption-based carbon emissions. Fan et al. (2012) applied a carbon emission input–output model with the statistics from city households from 2003 to 2009 [24]. They found that the average pollution level increased when consumption was more significant than CNY 10,000. Steininger et al. (2014) used the principles of fairness and economic performance to evaluate the possible benefits of transitioning to a consumption-based policy strategy [25]. They found that both (global) cost-effectiveness and equity can be strengthened if the developed countries' coercive climate policies are focused on commodity pollution. Girod et al. (2014) identified the five major consumption groups (food, housing, transportation, commodities, and services) [26]. They correlated their compliance with the greenhouse gas level expected by 2050 to meet the 28-climate target. Spaiser et al. (2019) introduced a recent study that indicates that the pattern of declining or reducing CO_2 emissions is reversed from a demand perspective, with the cost of depletion being diverted to developing countries [3].

National level carbon trade and emissions literature indicate that regional areas contributed to the majority of emissions. Sugar et al. (2012) presented extensive and accurate pollution records for Beijing, Shanghai, and Tianjin, where 10.7, 12.8, and 11.9 tons of equivalent per capita (t CO_2-eq/capita) carbon dioxide were emitted in 2006 [27]. They observed that 56% of the national footprint was associated with economic activity, 35% was associated with consumption for household sectors, and 9% was associated with consumption for government sectors. Minx et al. (2013) employed a mixed approach to estimate the carbon emissions of British cities and other human communities, directly relating industrial supply chains to urban demand and related lifestyles [28]. They contrasted consumption-based effects with expanded local projections of CO_2 emissions. They analyzed the driving factors affecting the population's carbon footprint in England. Researchers have also shown that 90% of the UK's population imports CO_2 emissions. Zhang et al. (2016) studied the sequential and spatial shifts in energy flows embodied through Chinese domestic exchange over 2002–2007 using MRIO models in which overall volumes of trade corresponded to 38.2% of the total nationwide direct principal energy production in 2002 and 62.9% from this in 2007, respectively [29]. Chang et al. (2016) recommended allocating expanded quotas for CO_2 emissions and reducing carbon intensity pressures based on the principle of information entropy [30]. It had been reported that the overall volume of primary energy usage by 2020 was below 4.8 billion tons of standard coal equivalent, comprising 62% consumption of coal, 10% consumption of natural gas, and 15% consumption of renewable energy. Yu et al. (2017) found that the building industry accounted for 18.1% of Australia's carbon footprint, compared to just 1.9% of direct emissions in 2013, resulting in high energy demand [31].

Global carbon trade and emissions literature indicate that developed and emerging countries contribute the majority of emissions. Peters et al. (2011) designed a commercially connected global CO_2 pollution database representing 113 countries worldwide and 57 commercial sectors from 1990 to 2008 [8]. They estimated that emissions from export-oriented products and services output rose from 4.3 Gt (20% of global emissions) of CO_2 in 1990 to 7.8 (26%) Gt of CO_2 in 2008. Atkinson et al. (2011) showed compelling evidence of the significant variability in carbon-intensive trade among continents, with most emerging countries convincing exporters of net virtual carbon [32]. They found that imports from South Africa, India, and China would face average tariff levels of 10% and 12% if the value of carbon is levied at USD 50/tons CO_2 for energy production and trade balance. Arce et al. (2016) worked with the Post-China (PC-16) countries, characterized by small wages and fast development [33]. The carbon reductions obtained by trade substitution are substantial in cases where the existing trading trend retained 13% of exports and 3.5% of global emissions. Companies, however, moved their activity directly or indirectly to countries that are very environmentally friendly. Karakaya et al. (2019) studied convergence tendencies in CO_2 emissions of 35 Annex B nations between 1990 and 2015 [34]. They combined these points and addressed the potential effects of integration research by using statistics on per capita emissions of CO_2 dependent on output and consumption. Safi et al. (2021) used CBE accounting methods that concentrated on the regional spread of manufacturing activities contributing to CO_2 emissions in E-7 countries [2]. As they are developing nations with ongoing industrial expansion, the coefficients for long-run connections are more significant than for short-run relationships, which has favorable influences on CO_2 emissions.

2.2. Consumption-Based CO_2 Emissions and Sustainable Development Goals

The link between sustainable development and pollution is extensively discussed in the previous literature. However, sustainability alone will not be enough to limit emissions, necessitating environmental legislation. To allow Asia's transition to a low-carbon-emission economy, Lee et al. (2018) proposed providing possible cleaner technologies accompanied by an environmental evaluation tool [21]. Life cycle assessment (LCA) approaches are frequently used in the energy industry; they may also assess the sustainability performance index in other industries. Danish et al. (2020) used a FMOLS model to determine the influence of climate change legislation on environmental protection across countries [20]. The present environmental control measures in the selected nations accomplish emissions reduction objectives, confirming the positive significance of environmental laws in carbon emission management. Shekhawat et al. (2021) investigated carbon pollution and socio-economic development for sustainable development for SAARC nations [19]. The findings reveal that the factors that affected CO_2 emissions differed by country. CO_2 emissions were reduced in most developing nations due to reducing poverty and natural circumstances. Using the entropy approach, Peng and Deng (2021) built 35 evaluation indicators based on fundamental urban development and low-carbon urban development levels to thoroughly examine economic growth, social advancement, and environment protection transformation [18]. Economic growth, social advancement, and environmental protection have all substantially improved due to the entire process of sustainable development.

2.2.1. CO_2 Emissions and Gross Domestic Products (GDP)

Economic development, energy demand, and CO_2 emissions are essential study topics. Economic growth is laden with declining in the environment's durability and functioning. The component of environmental management, innovation in pursuit of growth, is too frequently overlooked [35]. To combat declining environmental quality, Shan et al. (2021) proposed enhancing monetary and fiscal policy, reducing non-renewable energy prices, and boosting institutional performance [36]. However, Pejovi et al. (2021) believed that changes in GDP caused most changes in CO_2 emissions. Hence, lowering CO_2 emissions, in the long-term, may be accomplished by continually growing GDP [37].

2.2.2. CO_2 Emissions and Household Consumption (HC)

Huang et al. (2021) indicated that HC and financial development have a favorable short- and long-term impact on CO_2 emissions. In contrast, renewable energy usage and technological advancements have a negative impact [38]. Kerkhof et al. (2009) showed that the typical household in the Netherlands and the United Kingdom emits more CO_2 than the existing household in Sweden and Norway. Furthermore, in the Netherlands and the United Kingdom, CO_2 emissions from HC decrease as income rises [39]. On the other hand, Perobelli et al. (2015) found a concession between increased family satisfaction from spending and the increased obstruction in emissions resulting from the household consumption changes. As a result, by tracing the current actions of the Brazilian economy relating to high growth, variations in the economic circumstances, and their consequences on emissions, this study aims to measure the impact on carbon output [40].

2.2.3. CO_2 Emissions and Net Foreign Assets (NFA)

Because of the methodological design of the primary studies, there is a significant publication selection bias in the literature of NFA and CO_2 emissions. The findings imply an expected positive empirical outcome of economic growth on CO_2 emissions [41]. As a result, financial growth wrecks the ecosystem. Alshubiri and Elheddad (2019) showed that the relationship between foreign financial investment and environmental quality was an inverted U-shape [42]. The three proxies, foreign assets, monetary currencies, and remittances, significantly contribute to CO_2 emissions in the initial phases. However, after the threshold point is achieved, these proxies become "environmentally friendly" by contributing to CO_2 emission reduction.

Furthermore, a non-linear connection indicates that overseas investment in OECD nations increases the relevance of foreign capital as a proxy for ecosystems. However, foreign assets have worse ecological integrity. Sung et al. (2018) argued that dynamic panel bias must be eliminated to achieve more effective and convenient variable estimations. To accomplish this, they employed the time dummy and system generalized method of moments (GMM) model [43]. Finally, the findings reveal that NFA is a good predictor of ecosystems in the host nation, supporting the halo effect hypothesis that foreign investment decreases CO_2 emissions. In addition, the study shows the indication that higher industrial growth and production output enhance environmental quality. On the other hand, the national economic output has a detrimental influence on environmental quality.

2.2.4. CO_2 Emissions and Fertility Rate (FR)

Alola et al. (2019) [44] validated the importance of non-renewable energy usage in degrading air protection. In contrast, renewable energy usage was proven to promote sustainable development. Surprisingly, the unanticipated long-run fertility-ecological impact was linked to the EU member nations' different fertility rate data. Considering Chang et al.'s (2016) suggestion that limiting human activities' environmental consequences is essential, various research has gone deeper into the breadth of environmental viewpoints in the framework of ecological impact [30]. Sarkodie (2018) revealed that energy usage, agricultural production, economic expansion, field crops, fertility rate, and birthrate contribute to Africa's environmental deterioration and pollution, supporting global indicators for meeting sustainable development by 2030 [45].

2.2.5. CO_2 Emissions and Women Economic Rights (WER)

Women's traditional duties as caretakers, survival food producers, water and forest product collectors, and being a mother according to various strands of feminist thought, are to blame. Other theorists claim that women's positions and environmental conservation are intertwined since women's misuse and nature's subjugation are interdependent phenomena [46]. For these theoretical and empirical grounds, this study hypothesized that civilizations with higher equality for women would have fewer environmental consequences when adjusting for other aspects. They tested this theory using cross-national data analysis, concentrating on the link between female social standing and CO_2 emissions per capita. When monitoring GDP per capita, industrialization, urbanization, militarism, system location, overseas investment, age poverty rates, and level of democracy, CO_2 emissions per capita are reducing in cultures where women have strong political standing. This conclusion shows that efforts to increase gender equality throughout the world might complement efforts to reduce global environment and health degradation in general. Females are more involved in environmental restructuring programs and see environmental threats as dangerous [47].

2.2.6. CO_2 Emissions and Combustible Renewables and Waste (CRW)

Ben Jebli and Ben Youssef (2019) suggested that CRW helps to boost economic development and reduce CO_2 emissions. Farming output and CRW emerge to be interchangeable in the Brazilian economy. Rising CRW lowers agricultural value-added in the long-term and vice versa. Furthermore, increased financial expansion boosts agricultural and CRW output. It is recommended that Brazil continue to promote agricultural and biofuels production [48]. Ben Jebli and Belloumi (2017) proposed bidirectional short-run causation between CO_2 emissions and marine transport and a unidirectional causal relationship from real GDP, combustion renewables, and waste consumption to CO_2 emissions via rail transport. Long-term projections show that real GDP helps to reduce CO_2 emissions. However, short- and long-run unidirectional causalities exist between per capita CO_2 emissions and capita CRW consumption and per capita real GDP. Short-run unidirectional causation exists between per capita CRW consumption and CO_2 emissions. Our FMOLS and DOLS generated long-run predictions indicate that CO_2 emissions and CRW consumption benefit economic growth [49].

2.2.7. CO_2 Emissions and Government Expenditure (GE)

The positive impact is mediated by the influence of GE on income and, in turn, the impact of income on pollution. Cost hypotheses approaches were utilized to account for the dynamic character and probable endogeneity. Government spending on SO_2 is known to have a direct adverse impact on per capita emissions. In contrast, the immediate effect on CO_2 pollution is negligible. It becomes positive as income rises, but the unintended byproduct of CO_2 is harmful over most quarterly data [50]. According to Fan et al. (2020), regional emission disparity was caused by inequalities in industrial prosperity, demographic structure, and energy intensity, with discrepancies in government spending also playing a role. The primary source of emission inequality was inequalities in the spending structure, which were among these variables [51]. According to Halkos and Paizanos (2016), there is no evidence of a significant influence on contaminants with a greater global effect on the environment and human life expectancy, such as CO_2, emphasizing that environment protection accords are necessary for this scenario [52].

2.2.8. CO_2 Emissions and Service Economy (SE)

Hasmi et al. (2020) supported the idea of a service-induced environmental Kuznets curve (EKC). Increasing wealth significantly impacts environmental deterioration; however, once a certain threshold is reached, it recovers environmental degradation. The inverted U-shaped connection implies that the service sector uses less energy to reduce pollution. Furthermore, energy usage has an inverted U-shaped influence on CO_2 emissions, indicating that energy efficiency and renewable energy adoption have lowered pollution over time. In both the short- and long-term, trade openness increases CO_2 emissions. The quadratic income element has an adverse effect on CO_2 emissions, implying an identical sluggish pace of environmental quality improvement. According to the EKC theory, pollution rises during the early stages of economic development due to industrialization and urbanization. However, as the economy progresses and the service economy expands, and technology progresses, people become more worried about environmental concerns [53].

2.3. Granger Casualties between Consumption-Based CO_2 Emissions and Sustainable Development Goals

Adopting integrated and concerted plans and actions to achieve the SDGs by 2030 would minimize possible trade-offs and conflicts while maximizing efficiencies to promote various SDGs. The mitigation of short-lived climatic pollutants is an example of an intervention that contributes to different development outcomes. Haines et al. (2017) emphasized the interconnections between this pollution and the SDGs. They demonstrated how reducing emissions can help achieve several SDGs [54]. Scherer et al. (2018) used a consumption-based strategy to evaluate relationships in 166 countries, each of which was classified into four income categories. According to the study, pursuing social goals is often connected with more significant environmental repercussions. However, relationships vary widely between nations and are determined by individual aims. Carbon undergoes a minor change in both interactions than land and water. While efforts by both high- and low-income people are required, the wealthy have a more substantial influence in reducing humanity's footprint [55].

Cowan et al. (2014) investigated the GDP and CO_2 emissions relationship, a spillover hypothesis for Russia, a one-way Granger causation going from GDP to CO_2 emissions in South Africa, and the opposite link between CO_2 emissions and GDP in Brazil. There is no evidence of a Granger causal relationship between GDP and CO_2 emissions [56]. Gao and Zhang (2014) showed short-run unidirectional causation between economic growth and CO_2 emissions and energy consumption, respectively, using panel causality tests. At the same time, there is long-run bidirectional causation between power consumption and economic growth, electricity consumption and CO_2 emissions, and economic growth and CO_2 emissions [57]. Algarini's (2020) discovery of a positive relationship between carbon emissions and energy consumption has prompted governments to implement measures to reduce carbon emissions and control energy consumption to restore the ecosystem to its original state [58]. Using vector autoregressive models and Granger causality Wald tests, Kaygusuz (2012) found a bidirectional association between economic growth and energy consumption, economic growth and CO_2 emissions, and power production from gas and CO_2 emissions. Furthermore, a unidirectional correlation exists between energy consumption and CO_2 emissions and the rise of electricity generation from natural gas and between energy production from oil and CO_2 emissions [59].

Previously published studies are limited to either calculating consumption-based CO_2 emissions or environmental sustainability and climate policy recommendation. Most of these previous studies provide a mixed and inconclusive opinion about the CO_2 emission measure and its impact on sustainable development. However, very little is currently known about the impact of CBE on SDGs in the SAARC region. Sustainable development on climate change issues has not been appropriately clarified in the existing literature. Hence, this study tries to address this gap by input–output modeling with the economic indicators and carbon intensity, and calculating cointegration between CBE and SDGs indicators to measure the long-term effect of environmentally sustainable development.

3. Methodology

3.1. Data

In this study, 5 SAARC countries were chosen for carbon emissions comparisons, such as India, Bangladesh, Pakistan, Sri Lanka, and Nepal. Table 1 shows a set of socio-economic information of these countries. The study evaluated the CO_2 emissions accounting of these countries by using a Multi-Regional Input–Output (MRIO) model through carbon data. Industrial indicators of input–output tables were collected from the Asian Development Bank (ADB) 2015 database. A total of 35 industrial indicators have been selected for data analysis. Data on carbon emissions were received from the Eora 2015 emission database. The list of variables is presented in Table 2. All sustainable development data are available in the World Development Indicator database 2020 and datasets from Polity IV. Data periods were selected from 1972 to 2015.

Table 1. Socio-economic information of SAARC listed countries in 2015.

Country	Population (Millions)	Area (km^2)	GDP (Real Terms p.c. in USD Billions)	Household Consumption (USD Millions)	Fixed Capital Formation (USD Millions)	Govt. Consumption (USD Millions)	Export (USD Millions)
India	1311.05	3,287,263	2296.6	1,298,005	628,567	229,055	336,169
Pakistan	188.9	881,913	215.9	216,115	38,221	29,728	28,731
Bangladesh	161	147,570	156.6	141,572	56,622	10,500	28,054
Nepal	28.5	147,181	19.7	16,321	5768	2267	1339
Sri Lanka	21	65,610	76.3	56,727	21,480	7276	13,952

Source: World development indicators 2020.

3.2. Multi-Regional Input–Output (MRIO) Model

MRIO model may be a trendy method that allows researchers to investigate the whole supply chain and the related embodied emissions from any early stage of a commercial good [60]. The center participates in accounting nursing procedures for the country's economic input–output tables and inter-state trading matrices. This table illustrates the cash-flows at intervals and from the interconnected economies to and from the individual sector. It shows the entire supply chain of each sector.

By employing matrix representation and declining the indexes, we have

$$A = \begin{bmatrix} a^{11} & a^{12} & \cdots & a^{1n} \\ a^{21} & a^{22} & \cdots & a^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a^{n1} & a^{n2} & \cdots & a^{nn} \end{bmatrix}; \quad Q = \begin{bmatrix} y^{11} & y^{12} & \cdots & y^{1n} \\ y^{21} & y^{22} & \cdots & y^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y^{n1} & y^{n2} & \cdots & y^{nn} \end{bmatrix}; \quad P = \begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^n \end{bmatrix}$$

Therefore, the MRIO model can be written as:

$$M = Ap + q \tag{1}$$

where A indicates the transaction matrix; P is the final demand category.

Table 2. SDGs variables used in the reported models.

Variables	Units	Descriptions
Gross domestic product (GDP)	(constant 2010 USD)	Real gross domestic product per capita.
Household consumption (HC)	(constant 2010 USD)	Household consumption is the amount spent by a household on goods or services that are utilized to meet requirements or desires.
Net foreign assets (NFA)	(current LCU)	The value of a nation's abroad assets minus the value of its domestic assets owned by foreigners, adjusted for variations in valuation and exchange prices, is referred to as NFA.
Fertility rate (FR)	(births per woman)	The number of children born alive to women of that age during the year.
Women's Economic Rights (WER)	(scale 1–100)	Women's economic empowerment entails equitable participation in current markets, and control over resources over productive assets.
Combustible renewables and waste (CRW)	(% of total energy)	Solid, liquid, biogas, industrial, and municipal trash are all examples of combustible renewables and waste.
Measles Immunizing (MI)	(% of children ages 12–23 months)	% of children reaching 2 doses of measles vaccine aged 12–23 months.
Government expenditure (GE)	(% of GDP)	The amount of money spent by the government on acquiring goods and providing services such as education, healthcare, and social security is known as government spending.
Mortality rate (MR)	(per 1000 live births)	The total number of deaths under–5.
Tertiary education (TER)	(% gross)	Any level of education pursued beyond high school, tertiary.
Service Economy (SE)	(% of GDP)	Services, value-added.

Source: [3] and World development indicators 2020.

By addressing x, the new equation is

$$M = (I - A)^{-1}q \quad (2)$$

where $(I - A)^{-1}$ denotes the inverse matrix taking both explicit and implicit monetary inputs to fulfill one unit of ultimate monetary value; I indicates the identity of the diagonal matrix and the off-diagonal matrix value of zero.

To measure the consumption-based CO_2 emissions, this study spreads the input–output table with a vector for all regions with sectorial CO_2 emission coefficients, K

$$k = [k_1 k_2 \ldots\ k_n]$$

Therefore, the gross consumption-based CO_2 emissions can be estimated by:

$$CO_2 = k\,(I - A)^{-1}q \quad (3)$$

Here, CO_2 represents a vector of total carbon emissions, embodied in products and services consumed by final demand of all regions; k shows a vector of per unit of industrial production CO_2 emissions by all economic sectors in entire regions.

3.3. Fully Modified Ordinary Least Square (FMOLS)

This study includes FMOLS approaches to avoid the complexities of the cointegration of a single country emissions calculation method and improve reliability. MRIO model only estimates each industry sector's total number of emissions based on carbon intensity. Our study follows Pedroni [61], Phillips and Moon [62], and Kao and Chiang [63], who provided the propagation of the Phillips and Hansen [64] fully modified OLS estimation to panel settings. We can define the adjusted serial correlation adjusted terms and a dependent variable using estimations of the average long-run covariance $\acute{A}$, and $\acute{\Omega}$.

$$\bar{y}^{+}{}_{it} = \bar{y}_{it} - \acute{\omega}_{12}\acute{\Omega}^{-1}{}_{22}\ \hat{u}_2$$

Furthermore,

$$\lambda^{+}{}_{12} = \lambda_{12} - \acute{\omega}_{12}\ \acute{\Omega}^{-1}{}_{22}\ \acute{A}_{22}$$

The FMOLS estimator is then given by

$$\beta CBE = \left(\sum_{i=1}^{N}\sum_{t=1}^{T} X_{it}\ X_{it'}\right)^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T}\left(X_{it}y_{it}^{+} - \lambda_{12'}^{+}\right) \quad (4)$$

where CBE is consumption-based emissions, y_{it} and X_{it} indicate the equivalent data refined of the particular absolute trends, and $\acute{\omega}_{12}$ denotes the long-term average variance of u_{1it} dependent on u_{2it}. In the major case of individual-specific intercepts, $y_{it} = y_{it} - \bar{y}_i$ and $X_{it} = X_{it} - \ddot{X}_i$ have the demand variable.

3.4. Granger Casualty Test

Numerous methods have been applied in the literature to establish the evolution of directional causes among the variables. We employ the Granger casualty test to measure the unidirectional and bidirectional causes of CBE and SDGs variables. To examine the null hypothesis that y does not Granger-cause c, one must primarily choose which delayed values of y should be included in a univariate autoregressive of [65]:

$$c_t = \alpha_0 + \alpha_1 c_{t-1} + \alpha_2 c_{t-2} + \ldots + \alpha_m c_{t-m} + error_t$$

The autoregression is then improved by incorporating lagged x values:

$$c_t = \alpha_0 + \alpha_1 c_{t-1} + \alpha_2 c_{t-2} + \ldots + \alpha_m c_{t-m} + b_p y_{t-p} + \ldots + b_q y_{t-q} + error_t \quad (5)$$

This regression keeps every lagged value of y which is independently significant based on t-statistics, as long as they collectively offer predictive power to the regression based on an F-test (where null hypothesis has no explanatory power). P is the smallest, and q is the largest, lag length for which the lagged value of y is meaningful in the aforementioned enhanced regression equation.

4. Results and Analysis

4.1. Embodied CO_2 Emissions

The three last demand categories generate CO_2 emissions from the final consumption perspective: household consumption, government consumption, and capital formation. Among these three final demand categories, HC contributes the most to consumption-based emissions, which produce more than 62.39% of the overall consumption-based CO_2 emissions (see Figure 1). The substantial contribution of household consumption to consumer-based emission was motivated by increasing urbanization, extensive industrial activity, and government rules. India contributes the highest amount of household CO_2 emission, approximately 37.27 Gt. Nepal emits the lowest CO_2 emission, about 0.608 Gt.

Capital formation (CF) was the second leading source of emissions after household consumption. CF contributes 22.607 Gt of total CO_2 emissions in these five countries. India produces the highest emissions from CF, which is approximately 18.80 Gt. Depending on what capital goods countries and businesses spend, the carbon intensity of capital creation varies. CF is less carbon-intensive than HC in wealthy nations. Nepal and Sri Lanka have the lowest CO_2 emissions in the capital formation category, approximately 0.238 Gt and 0.268 Gt, respectively. The percentage of emissions generated by government consumption is 8.54% of the total emissions. India has the highest proportion of government consumption emissions, which is 5.138 Gt. The major cause of these emissions is the electric power sector's ongoing move away from coal and toward natural gas and biofuels.

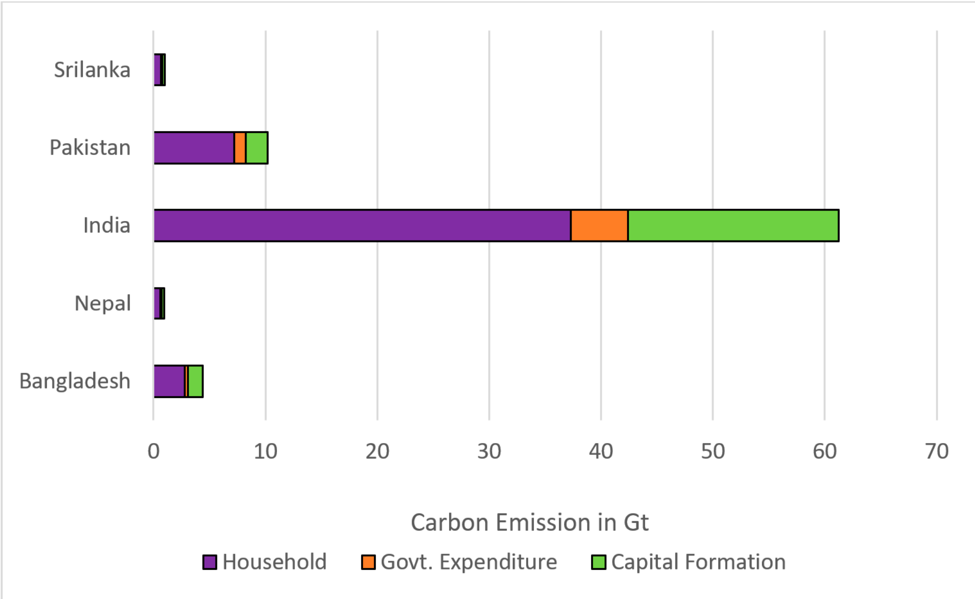


Figure 1. Embodied CO_2 emissions in three final demand categories.

4.2. Regional Emissions

Figure 2a shows the total emissions of imports for five countries in the SAARC region. Overall imports of emissions are highest in the two countries, India (16,889.32 Mt CO_2) and Bangladesh (15,907.88 Mt CO_2), respectively. Imports emissions from India are nearly three times higher than Nepal, five times higher than Pakistan, and nine times higher than Sri Lanka. Sri Lanka emits 1930 Mt CO_2 emissions, the lowest emissions among the five countries.

In the case of per USD GDP emissions (Figure 2b), Nepal ranks highest for CO_2 emissions (268,904.11 kg per USD GDP), and Bangladesh ranks second highest of emissions (101,582.88 kg per USD GDP). De-linking GDP growth from emissions or de-carbonization of the economy is crucial for achieving the twin objectives of maintaining economic growth while addressing climate change. However, absent significant action to reduce carbon intensity (CO_2/GDP) by its key trading partners, to the extent that current trends of a widening trade deficit continue, there are likely to be further increases in the SAARC's consumption-based emissions.

Annual per capita imports of emissions in Nepal, Bangladesh, Sri Lanka, Pakistan, and India are 0.185, 0.098, 0.091, 0.021, and 0.012 tons of CO_2 per person, respectively (Figure 2c). Nepal and Bangladesh contribute the highest emissions compared to other countries. We find that more developing countries tend to import more CO_2 emissions. As a developing country, India has the highest volume of emissions in imports. It can be argued that if a country can produce these goods more efficiently (with lower emissions) than other countries, this may be the preferred situation.

Overall exports of emissions are shown in Figure 3a. India contributes 14,924.03 Mt total exported CO_2 emissions. Pakistan contributes the second highest emissions (1058.09 Mt CO_2). Total exports of emissions of India are approximately 13 times higher than Pakistan, 25 times higher than Bangladesh (575.97 Mt CO_2), and 65 times higher than Sri Lanka (221.78 Mt CO_2). Nepal emits the lowest exported CO_2 emissions (125.14 Mt CO_2). The carbon intensity of GDP for total export emissions in Figure 3b shows that India and Pakistan emit considerable amounts of CO_2 compared to Bangladesh and Nepal. India emits a total of 6500.05 kg per USD GDP export emissions.

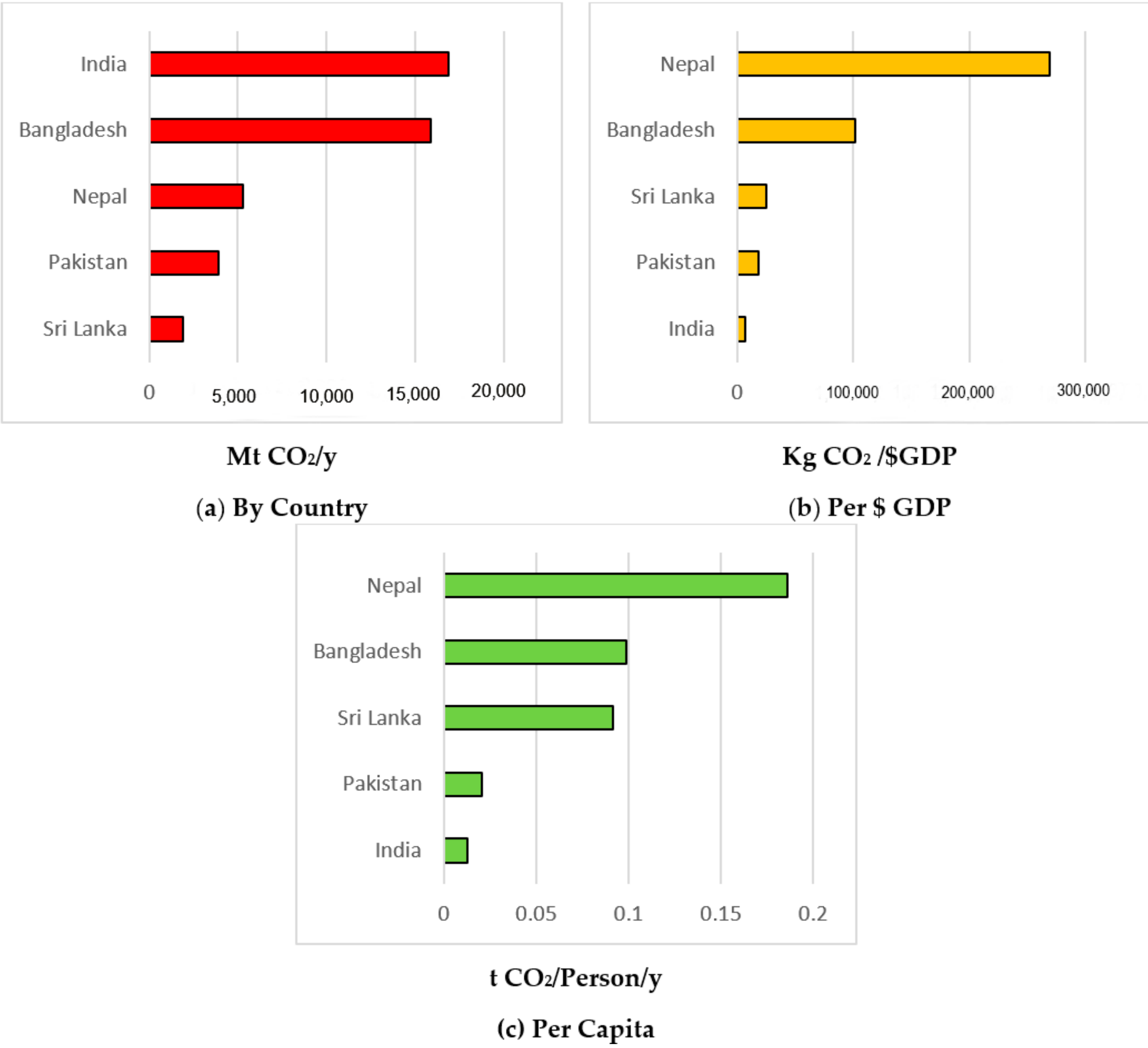


Figure 2. Regional emissions total five countries' total imports of emissions.

Annual per capita total exports of emissions in India, Sri Lanka, Pakistan, and Nepal are 0.012, 0.011, 0.006, and 0.004 tons of CO_2 per person, respectively (Figure 3c). It also means that if a country exports more goods and services than it imports, it will likely have disproportionately higher per capita emissions. Typically, industrialized nations with lower per capita CO_2 emissions will have more significant CO_2 emissions from imports and lower CO_2 emissions from exports as a counterbalance.

4.3. Cointegration Analysis

Table 3 reports that the long-term relationship between CBE and SDGs is obtained using FMOLS developed by Pedroni (2000) for the country level [61]. The result of correlation test and lag selection test can be found on the Appendix A (Table A2) and Appendix A (Table A3). In the case of GDP, the output of CBE is significant at 0.05% in Pakistan. The market price of all final products and services produced in a given period and the value that has been adjusted to take into account the effects of inflation is known as real-term GDP. Economic development is frequently blamed for ecological problems, assuming that more outstanding production means high CO_2 emissions. The result indicates that as Pakistan's income rises, so do their household-related services. HC in India and Pakistan have the highest positive long-term coefficient with CBE, which shows that these two countries' future household consumption patterns may increase environmental degradation. Suppose that any evaluation of the impact on the environment of HC in India and Pakistan is to be helpful to consumers. In that case, it must allow consumers to evaluate the items and services consumed in terms of ecological effects.

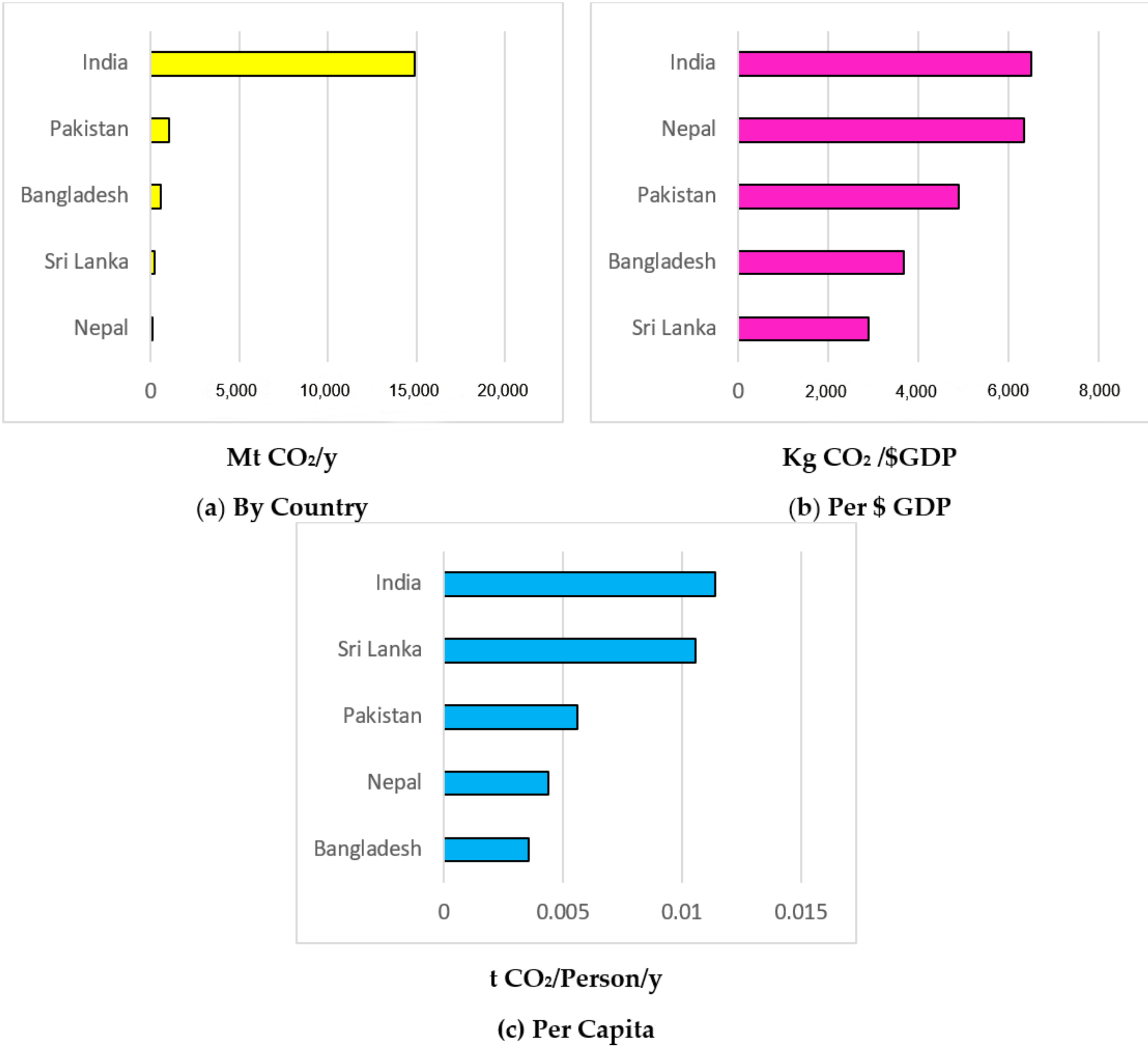


Figure 3. Regional emissions total five countries' total Exports of emissions.

NFA does not constitute any significant relationship with CBE for all SAARC countries. The FR impact on CBE is minimal in most countries. FR fosters collaboration between countries regarding the overall population, population age structure, and economic production. Only the long-term coefficient of Bangladesh is the highest. Lower fertility can boost income per person while lowering carbon emissions, removing a fundamental trade-off in most programs to limit global warming. Simultaneously, Bangladesh's anticipated economic and demographic development suggests that the nation would play a significant role in climate change.

Table 3. Long-term cointegration of consumption-based CO_2 emissions and sustainable development agenda.

Variables	Bangladesh		India		Pakistan		Nepal		Sri Lanka	
	Coef.	**t-Value**	**Coef.**	**t-Value**	**Coef.**	**t-Value**	**Coef.**	**t-Value**	**Coef.**	**t-Value**
ln_gdp	−34.88 (0.442)	−0.77	−465.85 (0.222)	−1.24	151.58 (0.009)	2.77	5.31 (0.426)	0.80	−0.49 (0.891)	−0.13
ln_hc	−1.13 (0.971)	−0.03	181.32 (0.005)	2.96	6.65 (0.866)	0.17	0.35 (0.824)	0.22	−5.28 (0.041)	−2.13
ln_nfa	0.01 (0.504)	0.67	0.01 (0.810)	0.24	3.11 (0.330)	0.98	−6.15 (0.668)	−0.43	−1.86 (0.085)	−1.78
ln_fr	209.57 (0.035)	2.20	−428.84 (0.235)	−1.21	−406.33 (0.074)	−1.84	−164.76 (0.885)	−0.14	195.45 (0.599)	0.53
ln_wer	−439.09 (0.076)	−1.83	−664.84 (0.027)	−2.31	−95.54 (0.805)	−0.24	−114.00 (0.035)	−2.19	−13.22 (0.876)	−0.15
ln_crw	−413.95 (0.082)	−1.79	−405.24 (0.000)	−6.88	263.01 (0.734)	0.34	−202.55 (0.003)	−3.17	−130.45 (0.009)	−2.78
ln_mi	−6.70 (0.853)	−0.18	−12.66 (0.066)	−1.90	−40.018 (0.612)	−0.51	14.32 (0.233)	1.21	10.37 (0.765)	0.30
ln_ge	0.01 (0.130)	1.55	4.23 (0.024)	2.37	1.61 (0.223)	1.24	1.38 (0.205)	1.29	4.98 (0.000)	4.15
ln_mr	210.71 (0.264)	1.13	−917.22 (0.349)	−0.95	−368.09 (0.404)	−0.84	63.55 (0.016)	2.53	−0.79 (0.941)	−0.07
ln_ter	351.64 (0.220)	1.25	580.80 (0.898)	0.12	160.07 (0.050)	2.03	−85.86 (0.321)	−1.00	−147.78 (0.012)	−2.65
ln_se	−177.12 (0.085)	−1.77	106.49 (0.015)	2.57	940.70 (0.102)	1.68	−10.31 (0.694)	−0.39	−24.95 (0.635)	−0.47

Source: Authors calculation. (Note: *p*-values for the statistical significance of the coefficients are given in parentheses.)

We also find that the impact of the WER on CBE is heterogeneous in India and Nepal. The long-term coefficients are negative in these two countries, and the values are lower than 1. The relationship between WER and CBE is statistically significant for India and Nepal. The result also indicates that men and women face and create climate change differently, with women bearing the brunt of the consequences [66]. Women are not intrinsically more sensitive to climate change than males. However, linkages between sexual identity, social dynamics, socio-economic systems, and cultural traditions cause women to experience climate change significantly. In India and Nepal, gender discrimination may overlap with racial grounds on other elements of identity, such as status, age, (dis)ability, sex, gender identification, nationality, and religion, amplifying the effects of climate change.

CRW, on the other hand, is an economic policy alternative for reducing the usage of the significant driver of global warming. However, specific political issues about energy inclusion might prevent countries from fully integrating. Most of the long-term elasticity of CBE output for CRW is negative, and the relationship is statistically significant except in Bangladesh. Pakistan constitutes the highest long-term CRW coefficient. The increased environmental consciousness of the population when it is heavily concentrated might explain the reduced energy use from significant pollutants. If the population resides in cities, the necessity of lowering carbon dioxide emissions generated by non-renewable energy would be more widely recognized.

At the same time, in most SAARC countries, the impact of MI indexes on CBE is not significant. We also found that, in India and Sri Lanka, the coefficient of GE is greater than 1, indicating that the impact of GE on CBE is high. These findings show that per capita production is not a strategy for lowering energy use from fossil fuels. Pollution control and enhancement of ecosystems are influenced by government spending on the climate and legislation governing the quality of the environment. However, increases in government spending do not always enhance environmental quality.

MR has a positive long-term coefficient on CBE only for Nepal. The adverse effects of environmental degradation may be evident in fetal growth, such as mortalities and infant mortality rates, two essential components of a nation's social sustainability. Mortality events equal the loss of potential human capital in a developing country such as Nepal, which can considerably benefit the economy's growth. Nevertheless, TER constitutes a significant positive long-term cointegration with CBE in Pakistan but negative in Sri Lanka. The result indicates that Pakistan and Sri Lanka's higher education scale and quality threshold affect regional carbon emissions per capita. However, TER may marginally increase emissions owing to economic growth. Still, the advantages of growing education exceed this, both in terms of education as a good itself and as a means of building resilience in the face of severe climate change consequences. In addition, India is the only country in the SAARC region with a high impact of SE on CBE. Emission reductions by limiting output will impact the economic revenue of some industries. This situation could, to some extent, stifle the country's economic progress. As a result, while analyzing the responsibilities of different sectors in a country, combined economic emission progress should be examined together. Finally, we find that the long-term coefficient that measures the impact of sustainable development variables on CBE is negative in most countries, but it is small.

4.4. Granger Causality Test

This study employs the Granger causality test to find a bidirectional and unidirectional relationship between CBE, GDP, HC, NFA, CRW, FR, WER, MI, GE, MR, TER, and SE. Table 4 shows the empirical results of the test where the null hypothesis that CBE does not cause GDP and vice versa is not rejected at a 5% level of significance for all countries. However, all SAARC listed countries have a unidirectional relationship between GDP and CBE except Pakistan. When the economy expands having increased GDP, different branches of the economy also grow with increased output. Thus, expansion of the economy will increase the demand for electricity and other energy usages, which will increase the CO_2 emissions level. India and Sri Lanka have a unidirectional relationship between HC and CBE because of their high household consumption levels. However, the null hypothesis is not rejected for CBE does not cause HC, which indicates the overall unidirectional relationship between these two countries with no impact of household consumption on CO_2 emissions. A bidirectional relationship has been found between NFA and CBE for Bangladesh and India, which depicts that net foreign assets or foreign investment have long-term effects on environmental degradation. However, Nepal shows a unidirectional relationship between NFA and CBE. CBE and GE also have a unidirectional relationship between Bangladesh, India, and Sri Lanka. Due to the higher rate of government expenditure in the national economy, these countries face an increased rate of consumption-based emissions. However, there is a reverse relationship, but the government needs to take several measurements and funding for controlling CO_2 emissions. Bangladesh shows a unidirectional relationship between FR and CBE. The result indicates that high fertility rate strategies may have less or no adverse impact on CO_2 emissions. In Sri Lanka, the high use of biomass in energy production causes an increased consumption-based emission.

Additionally, the unidirectional causal relationship may mean that the consumption of CRW is not strong enough to impact CBE. In India and Sri Lanka, bidirectional casualties have been found between TER and CBE. These feedback associations suggest that TER is responsible for CO_2 emissions in these two countries and promote environmental degradation. The study finds no causal relationship between service economy and CBE.

Table 4. Granger causality (Wald Test).

Null Hypothesis	Bangladesh		India		Pakistan		Nepal		Sri Lanka	
	F-Stat.	**Decision**	**F-Stat.**	**Decision**	**F-Stat.**	**Decision**	**F-Stat.**	**Decision**	**F-Stat.**	**Decision**
ln_gdp→ln_cbe ln_cbe→ln_gdp	6.241 (0.004) 1.124 (0.336)	Unidirectional	7.155 (0.002) 1.083 (0.349)	Unidirectional	1.313 (0.281) 0.029 (0.970)		1.270 (0.292) 4.502 (0.018)	Unidirectional	4.089 (0.025) 1.249 (0.298)	Unidirectional
ln_hc→ln_cbe ln_cbe→ln_hc	0.369 (0.693) 1.401 (0.259)		4.570 (0.017) 1.097 (0.344)	Unidirectional	1.387 (0.262) 1.881 (0.167)		0.085 (0.918) 0.182 (0.834)		3.552 (0.039) 2.211 (0.124)	Unidirectional
ln_nfa→ln_cbe ln_cbe→ln_nfa	5.909 (0.006) 2.540 (0.042)	Bidirectional	14.830 (0.004) 4.591 (0.016)	Bidirectional	1.826 (0.175) 1.048 (0.360)		3.664 (0.035) 0.668 (0.518)	Unidirectional	3.069 (0.051 1.256 (0.296)	Unidirectional
ln_crw→ln_cbe ln_cbe→ln_crw	1.099 (0.344) 0.713 (0.496)		0.717 (0.494) 0.250 (0.779)		0.681 (0.512) 0.581 (0.564)		0.613 (0.546) 1.075 (0.351)		4.382 (0.019) 1.281 (0.290)	Unidirectional
ln_fr→ln_cbe ln_cbe→ln_fr	4.762 (0.014) 2.005 (0.149)	Unidirectional	0.476 (0.624) 1.501 (0.236)		1.210 (0.309) 0.142 (0.867)		1.491 (0.238) 0.083 (0.920)		8.571 (0.867) 0.817 (0.449)	
ln_wer→ln_cbe ln_cbe→ln_wer	1.468 (0.243) 0.484 (0.619)		1.590 (0.217) 1.229 (0.304)		0.793 (0.459) 0.138 (0.871)		0.592 (0.558) 4.940 (0.012)	Unidirectional	0.193 (0.825) 0.435 (0.650)	
ln_mi→ln_cbe ln_cbe→ln_mi	0.221 (0.802) 0.212 (0.809)		0.341 (0.712) 0.182 (0.834)		0.390 (0.679) 0.816 (0.450)		2.141 (0.132) 2.737 (0.078)		5.592 (0.007) 1.043 (0.362)	Unidirectional
ln_ge→ln_cbe ln_cbe→ln_ge	4.445 (0.018) 1.186 (0.316)	Unidirectional	10.858 (0.000) 0.497 (0.612)	Unidirectional	2.109 (0.136) 2.458 (0.099)		0.093 (0.911) 1.438 (0.250)		3.539 (0.039 0.023 (0.977)	Unidirectional
ln_mr→ln_cbe ln_cbe→ln_mr	0.513 (0.602) 0.524 (0.596)		1.015 (0.372) 0.088 (0.915)		1.255 (0.297) 1.343 (0.273)		3.010 (0.061) 1.301 (0.284)		1.063 (0.355) 0.230 (0.795)	
ln_ter→ln_cbe ln_cbe→ln_ter	1.354 (0.270) 0.020 (0.979)		3.099 (0.051) 11.770 (0.001)	Bidirectional	1.571 (0.221) 0.213 (0.808)		2.295 (0.115) 0.205 (0.814)		8.051 (0.001) 5.784 (0.006)	Bidirectional
ln_se→ln_cbe ln_cbe→ln_se	0.954 (0.394) 0.467 (0.630)		0.771 (0.469) 0.200 (0.819)		0.836 (0.441) 0.158 (0.854)		2.038 (0.145) 2.765 (0.076)		0.015 (0.984) 0.370 (0.693)	

(Note: *p*-values for the statistical significance of the coefficients are given in parentheses.)

4.5. Stability and Residual Test

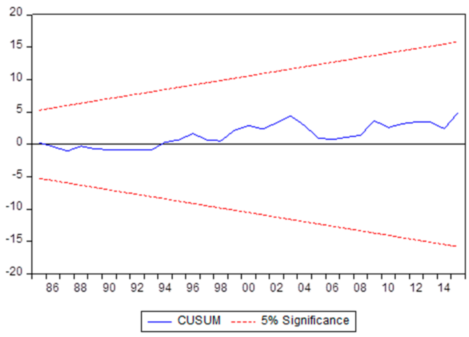
The residual and stability tests were used to confirm that our Granger causality model is adequate for empirical analyses and policy recommendations. The model passed the serial correlation and heteroskedasticity tests (as indicated in Table 5). The Breusch–Godfrey serial correlation LM test rejected the null hypothesis of a serial correlation for all countries except India. The p-value of the LM test for India is 0.036, which indicates the null hypothesis is not rejected for this country. Similarly, there are no ARCH effects in the model, as the F-statistics of the heteroskedasticity test for Bangladesh is 1.02 with a p-value of 0.45; Pakistan is 0.71 with a p-value of 0.72; Nepal is 0.35 with a p-value of 0.96; and Sri Lanka is 0.75 with a p-value 0.68. However, India shows a different result. The F-statistics of the heteroskedasticity test is 1.21 with 0.045, which denotes that the ARCH effect exists for this country.

Table 5. Results of the residual diagnostic test of the model.

Joint Test	Bangladesh		India		Pakistan		Nepal		Sri Lanka	
	F-Stats	p Value	F-Stats	p Value	F-Stats	p Value	F-Stats	p Value	F-Stats	p Value
Heteroskedasticity	1.021	0.451	1.206	0.045	0.701	0.727	0.353	0.964	0.755	0.679
Serial correlation	1.878	0.171	1.709	0.036	1.242	0.303	0.628	0.540	0.606	0.552

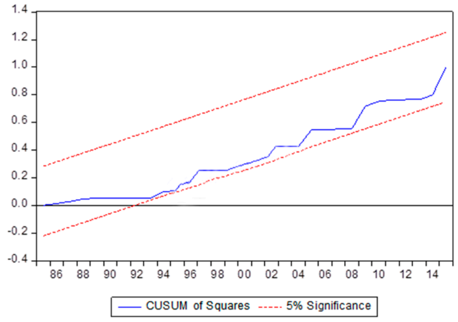
Serial correlation: a test using Breusch-Godfrey serial correlation LM test.

Our study used the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM square) tests to determine the stability of our models, which were based on a recursive regression stability test (shown in Figure 4). As shown in Figure 4, all countries' cumulative sum (CUSUM) plots fell within the critical boundaries at the 95% confidence level, indicating that our model is robust and stable. However, the result of CUSUM square in Figure 4(b2) shows a slightly different result for India, where critical bounds fail to indicate a 95% confidence level. Hence, we can conclude that our model is suitable for empirical analyses and policy recommendations.

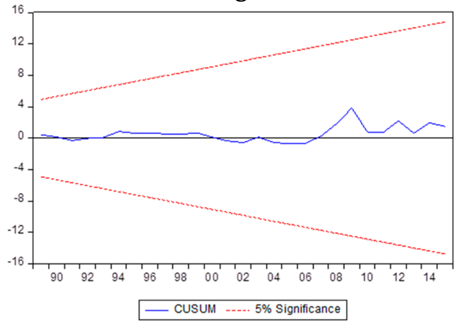


(a1) Bangladesh

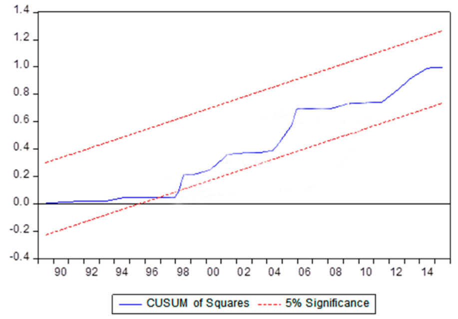
Figure 4. *Cont.*



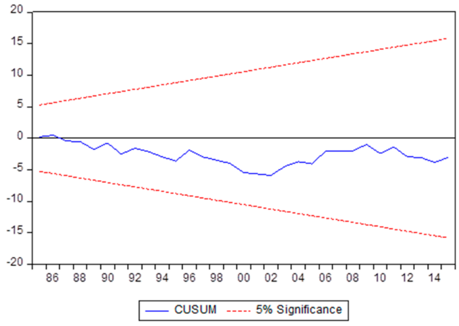
(a2) Bangladesh



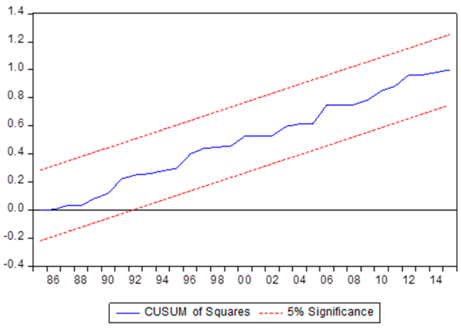
(b1) India



(b2) India

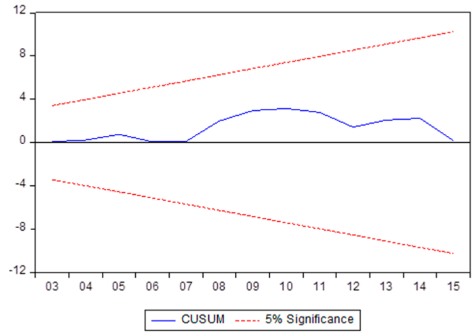


(c1) Pakistan

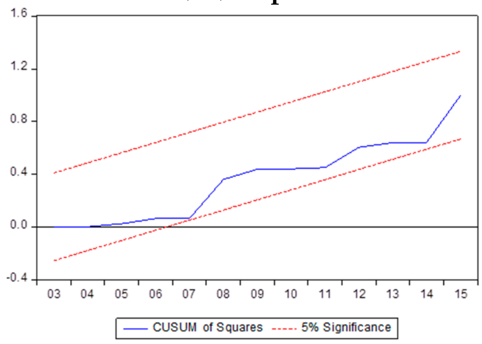


(c2) Pakistan

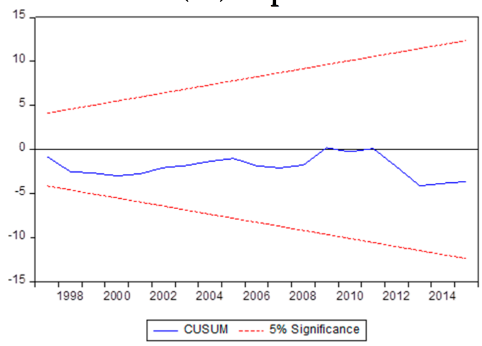
Figure 4. *Cont.*



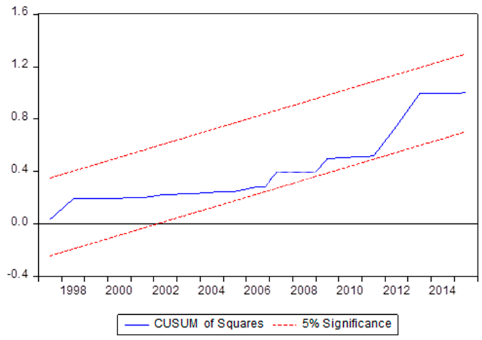
(d1) Nepal



(d2) Nepal



(e1) Sri Lanka



(e2) Sri Lanka

Figure 4. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUM square) stability tests.

5. Discussion

The present study aims to determine the consumption-based CO_2 emission in the SAARC region and measure the long-term effects of CBE on sustainable development. Concerning the first research question, the study finds that India ranks highest in domestic emissions (from domestic product consumption), emitting 61.22 Gt CO_2 emissions. In the case of imported emissions, Bangladesh and Nepal have the higher percentage of CO_2 emissions rates among the other three SAARC-listed countries. These two countries are primarily dependent on the import trade from other countries for their national demand. The consumption pattern of these two countries is very similar. Among household consumption, capital formation, and government consumption in Figure 1, HC contributes the most to consumption-based emissions, which produces more than 62.39% of the overall consumption-based CO_2 emissions. Due to increasing urbanization and extensive industrial activity, India contributes the highest household CO_2 emission, approximately 37.27 Gt. CF was the second leading source of emissions after HC. Our study is in line with Davis and Caldeira (2010) [67]; Knight and Schor (2014) [6]; and Peters et al. (2011) [8], who used the MRIO model for estimating worldwide CBE, as well as Zheng et al. (2020) [11] and Li et al. (2018) [68] for the national level. The result of domestic emissions and emissions embodied in the final demand support research question 1, which depicts that the MRIO model best describes the consumption-based CO_2 emissions.

Based on research question 2, we measure the long-term effect of consumption-based emissions on SDGs. Our finding in Table 3 demonstrates that an excessive pattern of consumption and production, especially in the developed nations, has been highlighted as a critical driver of the world environment's continuing deterioration. HC in India and Sri Lanka have the highest positive long-term coefficient with CBE. Most of the long-term elasticity of CBE output for CRW is negative and significant. Nepal and Sri Lanka constitute the highest long-term CRW coefficient. TER constitutes a significant positive long-term cointegration with CBE in Pakistan but negative cointegration in Sri Lanka. The result indicates that Pakistan and Sri Lanka's higher education scale and quality threshold affect regional carbon emissions per capita. In addition, India is the only country in the SAARC region with a high impact of SE on CBE. Our findings align with Szabo et al. (2016); Caballero (2019); and Scharlemann et al. (2020), who suggested that the factors that affected CO_2 emissions differed among countries [22,69,70]. CO_2 emissions were reduced in most emerging nations because of poverty reduction and environmental circumstances. However, Peng and Deng (2021), Tiba and Frikha (2019), and Togtokh and Gaffney (2010) provided a mixed opinion which indicates that ignoring the human issue from the environmental point will result in unsustainable development, allowing countries' economic growth and development to be unsustainable as well [18,71,72]. Thus, the long-term effect of the main predictors of sustainable development changes has varied on CBE in SAARC listed countries, supporting our research question 2.

For research question 3, we use the Granger casualty test to examine the unidirectional and bidirectional relationship between CBE and SGDs indicators. Most of the variables have a unidirectional relationship. GDP is the most influential SDGs indicator, which has a unidirectional relationship with CBE. Similar category results were found for Russia [56], Sub-Sahara African countries [57], China [73], Saudi Arabia [74]. Mohiuddin et al. (2016) and Yusuf et al. (2020) found a bidirectional relationship between GDP and CBE [75,76]. This result indicates that expansion of the economy will increase the demand for energy usage, which will increase the CO_2 emissions level.

On the other hand, GE also shows a unidirectional relation with CBE for India, Bangladesh, and Sri Lanka. Government spending directly influences allocation, improving people's income and raising demand for a sustainable future. When people's demands for the essential public good are met, demands for the ecosystem will rise if it is viewed as a fashion item. In terms of signs, our findings contrast with those of Khan et al. (2020), who showed a positive relationship between CO_2 and government spending in B&RI nations [77]. The results of Wang et al. (2019) and Apergis et al. (2020) are similar to our findings [47,78]. The cointegration technique was used in our study, which was not used in prior studies mentioned in our literature review section. As a result, our research sheds new light on the impact of government spending on environmental deterioration and the SDGs.

6. Conclusions and Policy Recommendations

The accounting for carbon dioxide emissions refers to processes undertaken to estimate the amounts of carbon dioxide generated by any entity. This method can be used for corporate and non-profit groups as part of environmental accounting. This study evaluates the CO_2 emission accounting of SAARC listed countries by using the input–output model and measures the long-term impact of CBE on SDGs 2030. Our findings show that Bangladesh, India, Pakistan, Nepal, and Sri Lanka produced approximately 4.39 Gt, 61.22 Gt, 10.22 Gt, 0.95 Gt, and 1.03 Gt in domestic emissions. Embodied carbon emissions in final demand groups in Figure 1 included household consumption, capital formation, and government consumption. India contributed the highest percentages of emissions in capital formation. Government contribution was meager in every country except India. The total imports and export emissions are shown in Figures 2 and 3, which indicate that India ranks highest among all other countries. The annual per USD GDP of imports of emissions was high in Nepal and lowest in India in 2015. However, annual per USD GDP of exports of emissions were large in India but lowest in Sri Lanka. The cointegration result shows that major SDGs indicators have no long-term adverse effect on consumption-based CO_2 emissions. However, the casualty analysis indicates that only GDP, HC, CRW have a unidirectional relationship with consumption-based emissions. All of these findings fulfill our expected research gaps.

CO_2 emissions accounting is widely accepted by various researchers and policymakers, which helps to incorporate in environmental policy areas represented by the SDGs. Based on our findings, a few suggestions are recommended. Firstly, CBE accounting is a deciding consideration in the mitigation strategies; however, the majority of global climate change negotiations have been endorsed production-based accounting, along with the UN Framework Convention on Global Climate Change (UNFCCC) and the City Protocol [23]. This approach elucidates the factors of pollution production; clearly, it increases cost efficiency and equity, tackles carbon leakage, supports competitive environmental benefits, and promotes technological diffusion. Secondly, to reduce CO_2 emissions in the SAARC region, policymakers must prioritize the fuel share within the combined market and replace significant emission intensity generating industries with lower emission intensity service sectors. Thirdly, the SDGs successfully changed people's perceptions of the environmental factor. This situation needs a one-of-a-kind platform for all countries and significant stakeholders to engage in authentic, active engagement. In reality, this implies that most of the essential tools for combating climate change are right where they should be, namely within the sectoral frameworks where essential stakeholders will be expected to perform. Including everything under the 'climate change' umbrella may make it more difficult for many people to commit to some of these actions [79,80]. It provides compelling examples of how unsurmountable political hurdles were overcome, resulting in a more technical framework that might lead to more effective execution in the future.

This study has some limitations. Firstly, the database of the input–output table is an essential indicator for CBE calculation. We only chose five SAARC listed countries from eight countries for CBE calculation due to the unavailability of the data. Secondly, a comparison between production-based and consumption-based emissions is not calculated, which would show the broader picture of each country's energy consumption and carbon emission. Finally, this study chooses only key indicators for SDGs 2030; however, SDGs majority indicators are not available in our dataset. This study is primarily based on carbon emissions and embodied pollution generated by domestic trade. However, water footprint was also significant, as was ecological footprint. Future work should combine all three metrics and evaluate geographic variability into a highly consistent framework, thereby offering an increasingly detailed panorama of atmospheric impacts caused by domestic trade.

Author Contributions: Conceptualization, M.M.R. and R.A.; methodology, R.A. and M.M.R.; software, M.M.R. and S.M.; validation, M.M.R. and A.I.M., M.Z.A. and A.H.M.M.; formal analysis, M.M.R.; investigation, A.H.M.M.; resources, S.M.; data curation, M.Z.A.; writing—original draft preparation, M.M.R., R.A. and A.I.M.; writing—review and editing, M.M.R., R.A. and A.I.M.; visualization, A.H.M.M.; supervision, R.A. and A.I.M.; project administration, A.I.M.; funding acquisition, A.I.M. All authors have read and agreed to the published version of the manuscript.

Funding: No funding was received for this research.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: All data to justify the proposed models are available from the manuscript.

Conflicts of Interest: We hereby declare that we do not have any conflict with other works.

Appendix A

Table A1. List of Abbreviations.

CBE	Consumption-Based Emissions
Gt	Gigatons
MARIO	Multi-Regional Input–Output
Mt	Metric tons
SAARC	South Asian Association for Regional Cooperation
SDGs	Sustainable Development Goals
UN	United Nations

Table A2. Correlation Analysis.

	ln_cbae	**ln_crw**	**ln_fr**	**ln_gdp**	**ln_ge**	**ln_hc**	**ln_mi**	**ln_mr**	**ln_nfa**	**ln_sec**	**ln_ter**	**ln_wer**
						Bangladesh						
ln_cbae	1.00											
ln_crw	−0.05	1.00										
ln_fr	0.49	0.12	1.00									
ln_gdp	0.68	0.08	0.58	1.00								
ln_ge	0.71	0.10	0.39	0.57	1.00							
ln_hc	0.50	0.11	−0.02	0.54	0.34	1.00						
ln_mi	−0.16	0.15	−0.35	−0.18	−0.09	0.01	1.00					
ln_mr	0.19	−0.03	−0.51	0.20	0.38	0.59	0.18	1.00				
ln_nfa	0.54	0.18	0.46	0.66	0.59	0.32	−0.07	0.18	1.00			
ln_sec	−0.14	−0.25	−0.07	−0.13	0.00	0.03	0.07	0.04	−0.04	1.00		
ln_ter	0.26	0.17	0.25	0.21	0.18	0.09	−0.08	−0.07	0.06	−0.14	1.00	
ln_wer	0.10	−0.09	0.28	0.26	0.13	−0.04	−0.07	−0.08	0.11	−0.12	0.20	1.00

Table A2. *Cont.*

	ln_cbae	ln_crw	ln_fr	ln_gdp	ln_ge	ln_hc	ln_mi	ln_mr	ln_nfa	ln_sec	ln_ter	ln_wer
						India						
ln_cbae	1.00											
ln_crw	−0.34	1.00										
ln_fr	0.12	0.28	1.00									
ln_gdp	0.53	0.10	0.47	1.00								
ln_ge	0.61	0.02	0.36	0.51	1.00							
ln_hc	0.46	0.27	0.53	0.61	0.31	1.00						
ln_mi	0.00	−0.34	−0.30	−0.02	0.01	−0.05	1.00					
ln_mr	0.28	−0.06	0.44	0.40	0.40	0.41	−0.07	1.00				
ln_nfa	0.44	0.22	0.52	0.41	0.59	0.57	−0.12	0.37	1.00			
ln_sec	0.14	−0.06	0.07	−0.10	−0.12	−0.08	−0.20	0.27	0.06	1.00		
ln_ter	0.41	0.18	0.16	0.39	0.49	0.49	−0.09	0.30	0.54	0.12	1.00	
ln_wer	−0.13	−0.01	0.11	0.18	−0.04	0.25	0.06	0.09	0.12	0.00	−0.33	1.00
						Pakistan						
ln_cbae	1.00											
ln_crw	−0.06	1.00										
ln_fr	−0.24	−0.22	1.00									
ln_gdp	0.41	−0.38	0.11	1.00								
ln_ge	0.28	−0.14	0.08	0.29	1.00							
ln_hc	−0.03	−0.13	0.24	0.17	−0.05	1.00						
ln_mi	−0.15	0.05	0.03	−0.02	−0.13	−0.05	1.00					
ln_mr	0.30	0.17	−0.60	0.18	0.05	−0.27	0.04	1.00				
ln_nfa	0.19	0.05	−0.11	0.13	0.07	−0.02	0.02	0.25	1.00			
ln_sec	0.13	−0.02	−0.10	−0.19	0.12	−0.10	−0.36	0.05	−0.02	1.00		
ln_ter	0.31	0.19	−0.10	0.14	0.06	−0.05	−0.01	0.09	0.11	−0.18	1.00	
ln_wer	−0.15	0.48	0.05	−0.22	−0.08	−0.04	−0.02	−0.12	−0.04	−0.14	0.04	1.00
						Nepal						
ln_cbae	1.00											
ln_crw	−0.54	1.00										
ln_fr	−0.03	0.04	1.00									
ln_gdp	0.40	−0.33	−0.28	1.00								
ln_ge	0.36	−0.37	−0.29	0.45	1.00							
ln_hc	0.01	0.09	0.20	−0.11	−0.08	1.00						
ln_mi	−0.03	0.34	0.20	−0.13	−0.26	0.02	1.00					
ln_mr	0.40	−0.19	−0.10	0.51	0.28	0.11	−0.13	1.00				
ln_nfa	0.17	−0.10	−0.05	0.48	0.22	−0.03	−0.02	0.59	1.00			
ln_sec	−0.07	0.18	−0.15	−0.08	−0.04	−0.11	0.01	−0.02	−0.10	1.00		
ln_ter	0.02	0.04	−0.13	0.16	0.22	0.03	−0.29	0.31	−0.12	−0.11	1.00	
ln_wer	−0.21	0.10	−0.16	0.05	0.06	−0.01	−0.10	0.25	0.50	−0.08	−0.18	1.00

Table A2. *Cont.*

	ln_cbae	ln_crw	ln_fr	ln_gdp	ln_ge	ln_hc	ln_mi	ln_mr	ln_nfa	ln_sec	ln_ter	ln_wer
						Sri Lanka						
ln_cbae	1.00											
ln_crw	−0.33	1.00										
ln_fr	0.45	−0.31	1.00									
ln_gdp	0.67	−0.14	0.59	1.00								
ln_ge	0.74	−0.17	0.51	0.48	1.00							
ln_hc	0.45	−0.22	0.37	0.52	0.60	1.00						
ln_mi	−0.26	0.10	−0.63	−0.39	−0.35	−0.32	1.00					
ln_mr	−0.10	0.06	−0.43	−0.01	−0.07	−0.11	0.22	1.00				
ln_nfa	−0.44	0.14	−0.08	−0.38	−0.43	−0.49	0.06	0.02	1.00			
ln_sec	0.02	−0.25	0.20	−0.03	−0.04	0.05	−0.06	−0.21	0.04	1.00		
ln_ter	0.08	−0.05	0.14	0.35	0.36	0.24	0.03	−0.01	−0.08	−0.24	1.00	
ln_wer	0.06	−0.09	0.13	0.02	−0.02	−0.14	−0.21	0.18	−0.01	0.04	−0.04	1.00

Lag Selection Criteria

An important practical issue for the implementation of the ADF test is the specification of the lag length p. If p is too small then the remaining serial correlation in the errors will bias the test. If p is too large then the power of the test will suffer.

Table A3. Automatic lag length selection based on SIC: 0 to 9. Newey–West automatic bandwidth selection and Bartlett kernel.

Methods	Bangladesh	India	Pakistan	Nepal	Sri Lanka
Null: unit root (assumes common unit root process) Levin, Lin and Chu t*	0.609 (0.028)	−1.669 (0.047)	−4.922 (0.000)	−1.028 (0.051)	−0.822 (0.005)
Null: unit root (assumes individual unit root process) Im, Pesaran and Shin W-stat	−5.319 (0.000)	−6.237 (0.000)	−18.825 (0.000)	−7.982 (0.000)	−6.822 (0.000)
ADF—Fisher Chi-square	102.206 (0.000)	140.284 (0.000)	197.311 (0.000)	166.370 (0.000)	115.730 (0.000)
PP—Fisher Chi-square	142.573 (0.000)	150.032 (0.000)	211.423 (0.000)	217.379 (0.000)	183.870 (0.000)

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