Global Value Chains Participation and Environmental Degradation in SAARC Economies

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Abstract: The rapid rise in the globalization of production processes, knowledge spillovers, grave environmental concerns, and sustainable development goals have attracted researchers and policymakers to explore the causes and consequences of these transformations. The developing countries such as The South Asian Association for Regional Cooperation (SAARC) countries are considered highly vulnerable to climatic changes. The purpose of this study is to examine the impact of global value chains participation both at the aggregated and disaggregated level on CO2 emissions in selected SAARC countries. The relationship among the modeled variables is estimated through the random effects and fixed effects models by using the robust standard errors as proposed by Driscoll and Kraay (1998). The findings indicate that the global value chains participation is pollution-intensive. Moreover, it is found that the global financial crisis of 2008 led to a decline in CO2 emissions. However, the emergence of World Trade Organization (WTO) particularly after the Doha agreement of 2001 has a significant positive impact on CO2 emissions in these countries. Based upon the empirical findings, some policy suggestions are also provided.

Keywords: **Global Value Chains; environmental degradation; panel data; SAARC economies.**

JEL Codes: C23; F14; Q53

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1. Introduction

In the last few decades, the world has undergone the substantial globalization of production processes, it is termed as Global Value Chains (GVCs). Instead of a one-way flow of goods and services across the borders, the production stages have been fragmented among different industries of different countries. Often labor-intensive multinational firms prefer to offshore their labor-intensive production processes to low-wage countries (Hammer, 2017a). Such as, the USA is offshoring a significant amount of its Information Technology (IT) services and manufacturing activities to India and China, respectively, because of the lower per-unit cost of production (Erber and Sayed-Ahmad, 2005), and some other factors[2] outlined by Hammer (2017b).

Currently, global value chains trade comprises about one-half of total international trade. The concept of GVC participation contains two components, one is Domestic Value Added (DVX) by country i in exports of country j, and other is Foreign Value Added (FVA) in exports of country i. It is also termed as backward participation. DVX is also known as selling linkage or forward participation that includes the transactions in which one country's exports are not fully absorbed by the importing countries, instead are embodied in the importing country's exports to other countries. On the other hand, FVA represents the foreign content or value-added previously imported from a foreign country embodied in a country's exports. To measure the GVC participation of a particular country or industry, we have to add the FVA and DVX. This combination of both the forward and backward participation entails the fact that a particular product will cross at least two borders for the country or industry to be regarded as participating in global value chains.

The SAARC region has shown significant performance in global value chains participation. India envisaged 41.37% of GVC participation in 2018 as compared to 38.57% in 2000. Bangladesh showed 30.68% in 2018 as compared to 24.97% in 2000. Pakistan's GVC participation was 40.14% in 2018 as compared to 29.71% in 2000. While Sri Lanka's GVC participation was 37.84% in 2018 with 37.19% in 2000. Nepal envisaged 36.72% in 2018. Whereas Bhutan and Maldives showed 55% and 43.47% in 2018, respectively.

[2] These factors are, flexible hiring, factor mobility within China, intra-firm trading, tariff reductions, better infrastructure, improved customs procedures, and accessibility to GVCs and growth markets.

Figure[3] 1 shows that Pakistan still relies heavily on forward participation, with a little share of foreign content in its exports. However, as compared to Pakistan, India has increased FVA considerably.

Figure 1. DVA and FVA by Pakistan

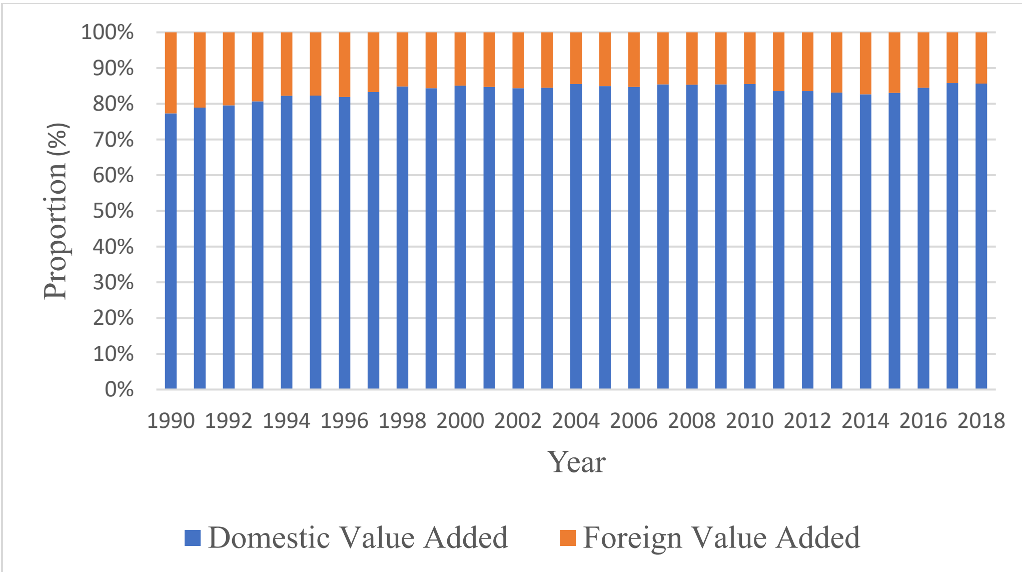
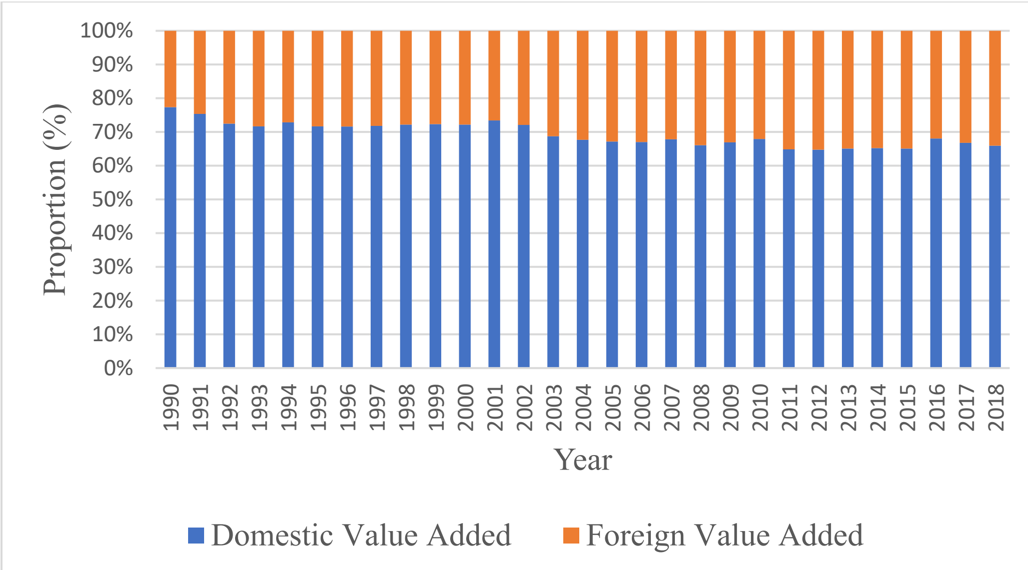


Figure 2. DVA and FVA by India

[3] Source of figures: UNCTAD-Eora Global Value Chain Database



Interestingly, the foreign value-added shares of exports by Bhutan and Nepal (see Appendix) have the greatest contribution in total GVC participation as compared to other member countries. Such disproportion shows that developing countries can have the opportunity to get benefits from GVCs through the channel of Foreign Direct Investment (FDI) inflows, or other factors (Antras, 2019).

Nevertheless, the rapid rise in globalization has caused greater environmental concerns across the globe. Particularly South Asia is one of the most vulnerable regions to climate change. According to the estimates by the World Bank[4], more than half of the South Asian population have been adversely affected by the climate change related environmental disasters in the last two decades. It is projected that further intensifying climatic changes can damage the living standards of more than 800 million South Asians. Chakraborty et al. (2018) found that the region is experiencing significant rise in frequency and degree of hot extremes. Similar findings were reported by Dimri (2019) and Dunn et al. (2020). Moreover, a report[5] by the Intergovernmental Panel on Climate Change (IPCC) predicts that the South Asia will experience longer monsoon, increase in droughts, and rise in heat by 2040. A World Bank study[6] of 2018 projected that the lack of climate-friendly policies in the South Asia will cause around 40 million migrations by 2050. GVC-based increase in cross-country flow of goods is fueling energy consumption that can further intensify the environmental damages. The challenge is to govern globalization and GVCs in a way that leads to

[4] Source: https://www.worldbank.org/en/region/sar/brief/integrating-climate-and-development-in-south-asia/integrating-climate-and-development-in-south-asia-region
[5] Available at: https://www.ipcc.ch/report/ar6/wg1/
[6] Available at: https://openknowledge.worldbank.org/handle/10986/29461

better environmental outcomes (Agarwal et al., 2021; Jun et al., 2021 Chishti et al., 2020; Antras, 2019; Panayotou, 2000). Hence dissociating GVCs from pollution emissions is essential for achieving the Sustainable Development Goals (SDGs) related to climate action. It is also pertinent to explore the individual impacts of backward and forward GVC participation on the environmental pollution. The backward participation entails foreign content in the exports of a country, whereas the forward participation involves domestic content in the exports of other countries. This fact indicates that the composition of imported goods and the nature of exported goods of a country also determine the production process and the underlying pollution emissions. For example, importing raw material and transforming it into the advanced exportable products a country requires different levels of production techniques and inputs than a country exporting the products with low capital intensity. Putting it differently, it is likely that the value-added exports of a country are relatively more pollution intensive than the other countries. Similarly, it is also likely that the imports by a country are more pollution intensive than the imports of other countries. Empirical evidence shows that the low-income countries are net exporters of pollution, whereas the high-income countries are net pollution importers (Zhang et al., 2019; Zhang et al., 2017; Peng et al., 2016). To this end, the present study explores the individual impacts of backward and forward GVC participation on CO2 emission in the context of SAARC countries. Figures[7] 3 through 8 given below depict an alarming fact about environmental affairs in SAARC countries. The figures show the time trend of carbon dioxide (CO2) emissions measured as metric tons per capita by selected SAARC countries. The unit of measurement is unform across all the figures. Each country's emissions are on a rising trend even though this region is facing huge climate change risks.

Figure 3. CO2 emissions in Pakistan

[7] Source: World Development Indicators

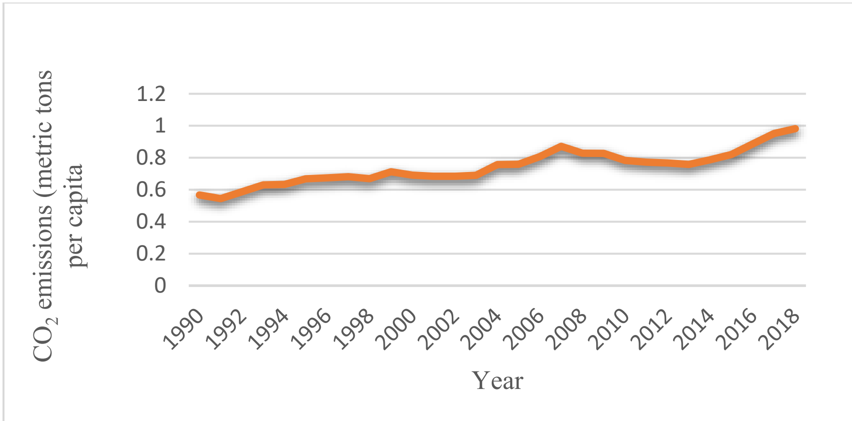


Figure 4. CO2 emissions in India

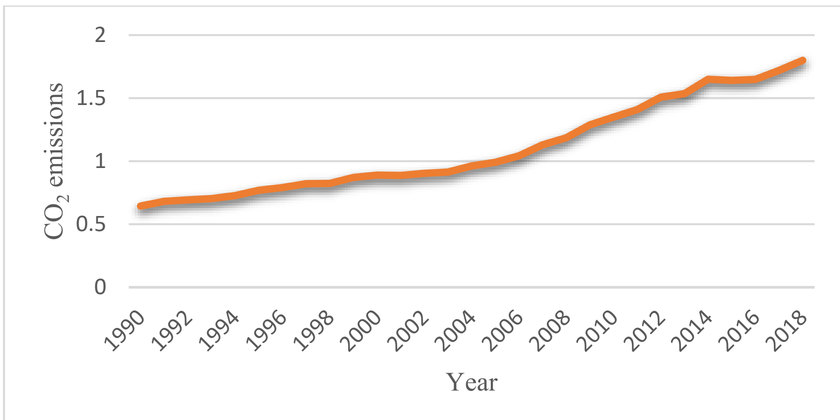


Figure 5. CO2 emissions in Bangladesh

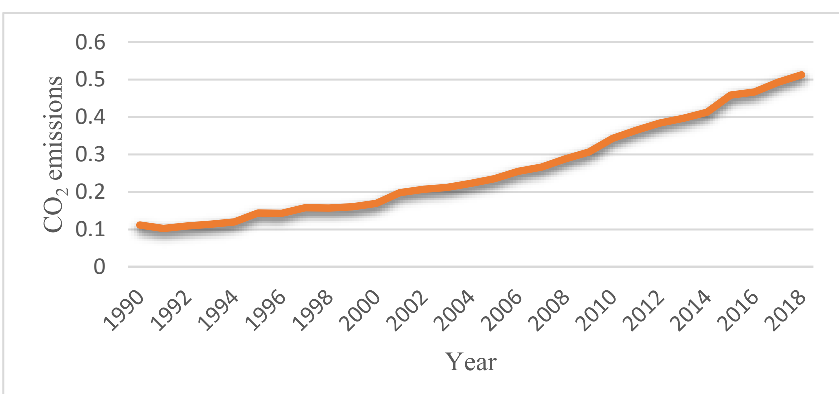


Figure 6. CO2 emissions in Sri Lanka

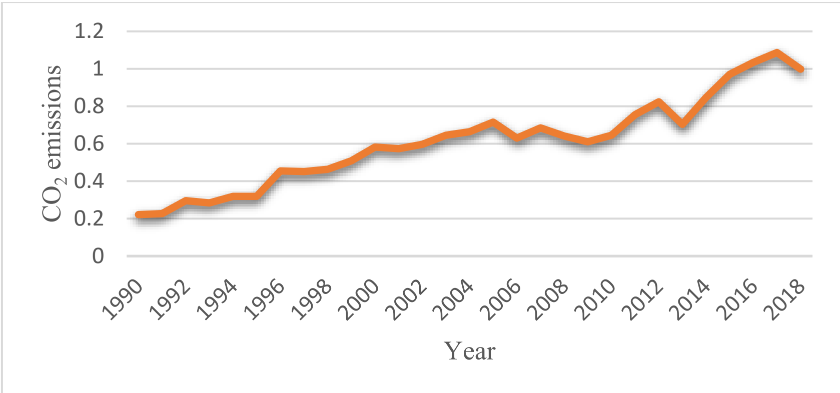


Figure 7. CO2 emissions in Nepal

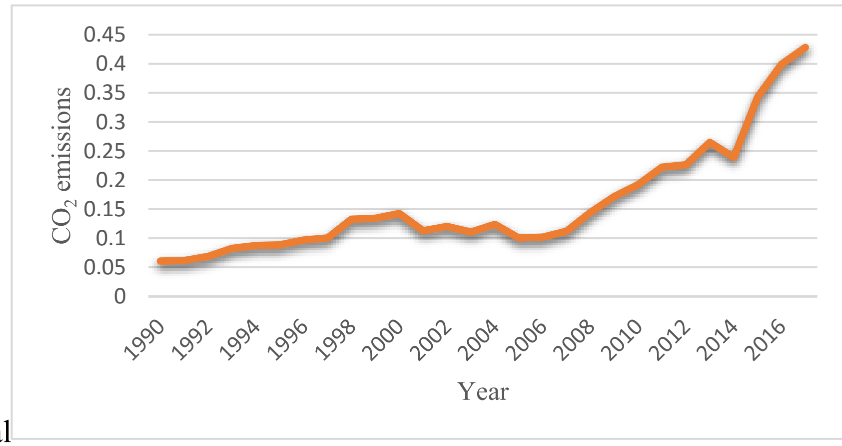
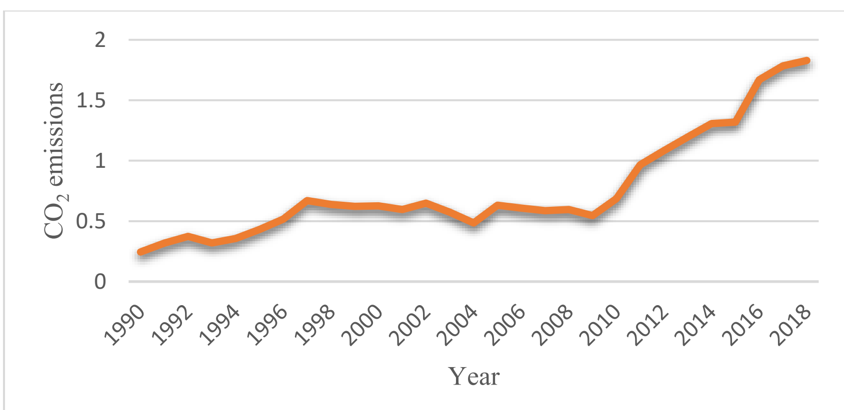


Figure 8. CO2 emissions in Bhutan



Given the context described above, the major contributions of this study are: i. role of economic integration through the traditional measures of international trade on CO_2 emissions is widely studied (le and Ozturk, 2020; Sun et al., 2019b; Zakaria; Bibi, 2019; Afridi et al., 2019, and Kim et al., 2018). However, the literature lacks the empirical work on individual impact of forward and backward GVC participation on CO_2 emissions, particularly in the case of South Asian countries. As per the knowledge of the authors, this is the ever first study that analyzes the impact of GVCs participation both at the aggregated and disaggregated levels on CO_2 emissions in seven SAARC countries; ii. in the GVC-CO_2 emissions relationship the study also accounts the impacts of the WTO, specifically after the Doha agreement and the global financial crisis of 2008. In contrast to the existing studies examining the role of financial crises on CO_2 emissions (Jalles, 2020; Sadorsky, 2020, and Guan and Jiang, 2017), this study provides an explicit and fresh evidence by capturing both pre- and post-financial crises differential in the CO_2 emissions of the selected SAARC countries. Moreover, the SAARC region was ignored in terms of exploring the impact of WTO accession on its CO_2 emissions; however the current study has paid proper attention on this important issue.

The remaining parts of the study are organized by providing a literature review in section 2, the theoretical framework in section 3, Data and methodology in section 4, empirical results and discussion in section 5, and a conclusion with policy implications at the end.

2. Literature review

This section provides a review of relevant studies on the relationship of global value chains trade, international trade, and other factors with environmental quality with a particular focus on empirical evidence from the SAARC region.

2.1. Global value chains and environmental quality

Globalization and the resulting rise in production networks are crucial for economic growth. The World Economic Forum (2013) estimates that reductions in GVC trade barriers, such as border administration and non-tariff barriers to trade, could raise global GDP by 5% and international trade by 15%. However, whether the enhanced GVC leads to a rise in pollution emissions, or it can reduce is the matter of research focus. As compared to traditional trade, GVCs have strong potential to promote the transfer of clean technology because of their greater impact on the growth rates of participating countries (Antras, 2019). The findings of Assamoi et al. (2020) partially support the claim of Antras. The study found that an increase in GVC participation can significantly reduce $CO2$ emissions in the selected Asian economies, namely Combodia, China, India, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Thailand, and Vietnam. Moreover, trade openness also leads to a fall in emissions. Similarly, Wang et al. (2021) examined the role of GVCs in pollution determination in the case of developing countries. The study found that when GVCs are below the certain threshold, technological progress causes pollution, however, it is not the case when GVC participation crosses the threshold.

On the other hand, some studies find that there exists an inverted U shape relationship between GVC activities and CO2 emissions (Wang et al., 2019; Yasmeen et al., 2019). These studies claim that at the initial stages of GVC participation, pollution increases, however after a certain threshold further increase in the GVCs results in a fall in pollution. Contrary to the above studies, Zhang et al. (2021) pointed out that GVCs are much more pollution intensive as compared to domestic production. This study also found that major contributors of emissions in the context of GVCs are emerging economies, as well as services and manufacturing sectors. Duan et al. (2021) also reached a similar conclusion in the case of 35 industries of 40 economies.

2.2. International trade and CO2 emissions

Literature on examination of linkages among traditional trade openness and globalization measures and pollution show that trade openness can significantly reduce CO2 emissions in SAARC economies (Afridi et al., 2019), however according to Sun et al. (2019a), there is an inverted U shape relationship between international trade and the emissions. Nevertheless, the majority of studies maintain that trade openness and conventional measures of globalization lead to higher carbon emissions and pollution (le and Ozturk, 2020; Sun et al., 2019b; Zakaria and Bibi, 2019). Kim et al. (2018) examined the impact of trade openness on CO2 emissions. The results confirmed the validity of the pollution haven hypothesis by showing that expansion in the trade of developing countries with the developed countries leads to a rise in CO2 emissions. Similarly, Ahmed et al. (2016) analyzed the impact of trade openness on CO2 emissions in SAARC countries. The findings of the study reveal that trade openness enhances CO2 emissions. Rahman et al (2020) also found a bidirectional relationship between trade openness and CO2 emissions for the SAARC countries. Khalid et al. (2020) also found that trade openness leads to environmental degradation in SAARC countries, except Nepal. However, Murshed et al. (2021) concluded that the rise in inter-regional trade in the south Asian economies significantly reduces CO2 emissions.

2.3. Other determinants of CO2 emissions

The determinants of CO2 emissions in terms of fossil fuel and renewable energy consumption, FDI, urbanization, population, and economic growth have been examined in several empirical studies (Xue et al., 2021; Sultana et al., 2021; Latief et al., 2021; Naseem and Ji, 2021; Khan and

Bin, 2020; Rahman, 2020; Waqih et al., 2019; Nasreen et al., 2017; Rehman and Rashid, 2017; Hanif and Gago-de-Santos, 2017; Wang et al., 2016; Fodha and Zaghdoud, 2010; Diao et al., 2009; Tao et al., 2008). Some of these studies found trade openness, FDI, and energy consumption to be positively affecting pollution emissions, and others concluded that trade openness and FDI can reduce emissions. Nevertheless, as argued by Antras, the potential adverse impacts of international trade and GVC trade can be somewhat moderated by institutional quality (Xue et al., 2021; Godil et al., 2020).

In sum, the literature provides mixed evidence regarding the impact of international trade openness and GVC trade participation on pollution emissions. The majority of the studies used traditional measures of globalization, such as KOF index and share of total trade as a percentage of GDP. However, the literature lacks empirical evidence on examining the role of GVC participation on CO2 emissions in SAARC economies, a region highly vulnerable to climate change risks. Hence, this study aims at providing an empirical analysis of GVC participation and CO2 emissions per capita in the SAARC region.

3. Theoretical Framework

The environmental Kuznets curve hypothesis (EKC) postulates that income level plays a momentous role in environmental performance. At the early stages of economic development, the environment of a country deteriorates as a result of massive industrialization, however after a certain level of income, quality of environment starts improving due to advancement in technology (Rahman, 2017; Rahman and Alam 2022a; Panayotou, 2003). This indicates the existence of non-linear inverted U-shaped relationship between the economic growth and environmental quality (Rahman, et al 2021; Dogan and Turkekul, 2016; Rehman et al., 2012), which is popularly known as EKC hypothesis (Rahman and Alam 2022b, Rahman and Alam, 2021) While thinking about international trade, the flow of goods across the countries generates CO2 emissions that directly damage environmental health. However, in the world of GVCs, the same value-added is transported multiple times before reaching the final users. This phenomenon entails the fact that transportation of goods in GVCs results in higher CO2 emissions than traditional trade. Likewise, the concept of hyper-specialization in GVCs also indicates the pollution haven hypothesis, in which the lead firms from developed countries may shift pollution-intensive stages of production to the countries where environmental norms are not stringent, hence circumventing the cost of strict environmental policies (Duan et al., 2021; Antras, 2019).

However, it is also probable that GVCs can reduce the environmental concerns for at least two reasons. First, increased GVCs participation can promote economic growth (Kummritz, 2016), which in turn leads to increased demand for a better environment (Rahman, 2020). Second, GVCs have great potential for environmental-friendly technology transfer, which can improve environmental quality in countries' participation in GVCs.

Some empirical studies show that the high-income countries are net importers of pollution, while the low-income countries are net exporters (Zhang et al., 2017; Peng et al., 2016). Hence, it is expected that the individual impacts of backward and forward GVC participation on CO2 emissions will be significantly different. To estimate the embodied emissions through backward and forward GVC participation, one has to follow Leontief (1936). This study explained that the inter-relationships amongst different industries around countries can be stated as several inter-industry/country dealings structured into matrices, where every column denotes the essential inputs from other countries/industries to produce the certain quantity of the product shown by that column. Upon standardization, the coefficient table exhibits the quantity and type of intermediate level inputs required in the production of a unit of product. We can use these coefficients to estimate the amount produced in all phases of production that is required to produce one unit of final product. When the production flows linked with a specific quantity of ultimate demand are known, we can estimate the emissions during the course of the economy by multiplying these product flows with the coefficient of emission intensity in each country (Meng et al., 2015).

Following the framework provided by Meng et al., (2015), we consider the case of a two-country world (domestic and foreign), where *N* industries of each country produce tradable goods. Those goods from each sector can either be utilized directly or used as intermediate inputs. Moreover, every country exports both intermediary and final goods. The whole gross output produced by country s will be used as either an intermediary or a final good at home or foreign. It can be expressed as,

$$X^s = A^{ss}X^s + Y^{ss} + A^{sr}X^r + Y^{sr} \quad r, s = 1, 2 \qquad (1)$$

Where, X^s is gross output vector of country s. It has a dimension of N×1. Y^{sr} is the $N \times 1$ final demand vector that provides demand in country r for final goods produced in country s, and A^{sr} is the $N \times N$ input matrix of coefficients, showing intermediate use in country r of goods produced in country s. In the superscripts, r is the destination country and s is the producing country. In equation (1), the expression $A^{ss}X^s + Y^{ss}$ denotes the domestic use of products, whereas $A^{sr}X^r +$

Y^{sr} shows the exports abroad. Further, these can be divided into intermediate consumption $A^{ss}X^{s} + A^{sr}X^{r}$, and final consumption $Y^{ss} + Y^{sr}$. The system of trade and production can be composed as a multi-country IO model in the following notation,

$$\begin{bmatrix} X^{s} \\ X^{r} \end{bmatrix} = \begin{bmatrix} A^{ss} & A^{sr} \\ A^{rs} & A^{rr} \end{bmatrix} \begin{bmatrix} X^{s} \\ X^{r} \end{bmatrix} + \begin{bmatrix} Y^{ss} & + & Y^{sr} \\ Y^{rs} & + & Y^{rr} \end{bmatrix} \qquad (2)$$

Equation (2) shows a clear difference between final consumption (Y) and intermediate consumption (AX). The intermediate consumption can be either used domestically or exported/imported. Similarly for the final consumption. Here, the final consumption is considered as exogenous, whereas consumption of intermediates is endogenous. Rearrangement of the terms provides the following expression,

$$\begin{bmatrix} X^{s} \\ X^{r} \end{bmatrix} = \begin{bmatrix} I - A^{ss} & -A^{sr} \\ -A^{rs} & I - A^{rr} \end{bmatrix}^{-1} \begin{bmatrix} Y^{ss} & + & Y^{sr} \\ Y^{rs} & + & Y^{rr} \end{bmatrix} = \begin{bmatrix} B^{ss} & B^{sr} \\ B^{rs} & B^{rr} \end{bmatrix} \begin{bmatrix} Y^{s} \\ Y^{r} \end{bmatrix} \qquad (3)$$

In the above expression, B^{sr} indicates an $N \times N$ matrix, which is the matrix of the total requirement that provides the output in producing country s required for a unit rise in final demand in country r. The diagonal terms B^{ss} are different from the Leontief inverse $L^{ss} = (I - A^{ss})^{-1}$ because of the addition of terms on off-diagonal through the inverse matrix operation. $N \times 1$ vector Y^{s} offers global use of final products from country s, together with final products sales domestically Y^{ss} and exports of final products Y^{sr}.

From equation (3), the intuition can be explained as, when \$1 of final products is manufactured, emissions (P) are created as a first round. These are considered as the direct emissions brought by the \$1 of final goods produced. To produce these goods, intermediate inputs are required, and the production of these intermediates also results in emissions. This can be termed as the second round of emissions which is brought by the \$1 of final goods. This process continues through further rounds of production during the course of the economy, as intermediate inputs are utilized to produce other intermediates. The total quantity of emissions caused by the \$1 of final goods is equal to the sum of direct and indirect emissions. Finally, we have:

$$\begin{aligned} Emissions &= P + PA + PAA + \cdots \\ &= P(I + A + A^{2} + A^{3} + \cdots \\ &= P(I - A)^{-1} \\ &= PB \qquad (4) \end{aligned}$$

4. Materials and Methods

This section provides the discussion on the econometric model, data, construction, and source of variables, tabular review of the data, empirical framework of the present study.

4.1 Econometric model

Given the theoretical framework and proposed hypotheses presented in the above sections, and following Jin et al. (2022) and Antras (2019), we have framed the following econometric model for empirical estimation:

$$COE_{it} = \alpha_0 + \alpha_1 GVCP_{it} + Z\gamma + \mu_{it} \quad (5)$$

$$COE_{it} = \rho_0 + \rho_1 BWP_{it} + \rho_2 FWP_{it} + Z\sigma + \mu_{it} \quad (6)$$

In the above equations, i refers to the country, and t shows time in years. COE shows CO2 emissions calculated as metric tons per capita. $GVCP$ shows GVC participation index, BWP denotes backward GVC participation, FWP stands for forward GVC participation, and Z denotes vectors of control variables. Whereas μ_{it} is denoting error term.

4.2 Variable construction and data

GVC participation index is calculated by summing the countries' forward and backward GVC participation in total value-added exports (Wang et al., 2017). Mathematically, is represented as follows:

$$GVCP = \frac{BWP}{VAE} + \frac{FWP}{VAE}$$

$$GVCP = \frac{BWP+FWP}{VAE} \quad (7)$$

In equation (7), VAE denotes total value-added exports. To empirically examine the relationship between proposed variables, data of seven SAARC countries[8] for the period 1990-2018 will be utilized. CO2 emissions are measured in metric tons per capita; GDP is given in per capita measured in constant US$, and urbanization is calculated as the urban population percentage of the total population. The model also includes the dummy variables of the global financial crisis of 2008 and WTO. In the case of former 0 is assigned to years before and after 2008 and 1 is for 2008. However, the effect of later is captured by assigning 0 to years before 2001 (the year of the Doha agreement[9]) and 1 otherwise. Data of all the indicators except the GVC indicators used in

[8] See Appendix Table A.1 for the list of selected countries

[9] Source: WTO website

the empirical analysis are collected from the World Development indicators database[10]. Data related to GVC are taken from EORA[11] global supply chain database.

In order to evaluate the characteristics of data, the descriptive analysis of the variables is presented here (see Table 1). A tabular summary of the description, measurement, and sources of modeled variables are presented in Table 2.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
COE	203	0.816	0.733	0.05	3.704
GVC Index	203	38.081	9.516	22.749	59.243
FVA Index	203	15.766	9.37	4.299	39.644
DVX Index	203	22.313	6.008	6.86	35.036
GDP	203	2186.036	2376.081	437.536	9823.091
Urbanization	203	26.277	7.934	8.854	40.895

Source: Authors' calculations from World bank's data

Table 2. Summary of variables' description, measurement, and source

Variable	Description	Measurement	Transformation	Source
COE	CO2 emissions per capita	Metric tons per capita	Natural log.	World bank
GVC Index	GVC participation index	Total GVC (FVA+DVX) as percentage of gross exports	Natural log.	EORA global supply chain database
FVA Index	Foreign value-added index	Total foreign value-added as percentage of gross exports	Natural log.	EORA global supply chain database
DVX Index	Domestic value-added index	Total domestic value-added index	Natural log.	EORA global supply chain database
GDPC	GDP Per capita	GDP per capita calculated as constant 2015 US$	Natural log.	World bank
Urbanization	Urban population	Percentage of total population	Natural log.	World bank
FC	Dummy of Financial crisis 2008	Dummy (0 for before and after 2008, 1 otherwise)	Dummy var.	-

[10] Source: https://databank.worldbank.org/source/world-development-indicators
[11] Source: EORA global supply chain database https://worldmrio.com/

WTO	Dummy of the emergence of WTO	Dummy (0 for before 2001 (Doha agreement year), 1 otherwise))	Dummy var	WTO

4.3 Empirical Framework

This study aims to analyze the impact of GVC participation in the presence of control variables such as urbanization, dummies of the financial crisis of 2008 and emergence of WTO, and GDP per capita on CO2 emissions for a panel of seven SAARC countries. Given the sample countries' border sharing, trade linkages, and climatic similarities, we can expect the prevalence of Cross-Sectional Dependence (CSD) among these countries. Hence, if CSD is not adequately considered in empirical analysis, the result can be biased (Phillips and Sul, 2003). To this end, the empirical analysis of the present study is provided in three steps. First, we have checked for potential CSD among the countries by employing Friedman's (1937) tests statistic, Frees (1995), and Pesaran CD tests. (See table 3) Mathematical expression of the CSD test developed by Pesaran (2004) as given below:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=0}^{N-1}\sum_{j=i+1}^{N}\rho ij\right)} \qquad (4)$$

In equation (4), T denotes time in years, N represents the cross-section entities in the data. Whereas ρ_{ij} shows the cross-sectional correlation of error terms among i and j.

We have applied a second-generation unit root test (Pesaran 2007) for identifying the order of integration of modeled variables (table showing the order of integration is given in appendix 2b). Since the order of integration of focus variables of this study, such as foreign value-added and domestic value-added is zero, hence we are unable to proceed with estimating the relationship with second-generation techniques.

Therefore, the relationship among the modeled variables is estimated through the random effects and fixed effects models by finding the robust standard errors as proposed by Driscoll and Kraay (1998). They demonstrate that Driscoll and Kraay standard errors are robust to cross-sectional and temporal dependence. The fixed-effects model uses the dummy variables of countries to capture the country-specific effects. Furthermore, it can also be used to find time-specific effects in the panel. The random-effects model approximates an additional parameter of a time-variant dummy. These models differ in a term of capturing the time-variant and invariant characteristics in the panel settings. The intercept of the fixed effects model provided a fixed effect time-invariant dummy variable of each cross-section element. However, the random-effects model gives the intercept which contains a time-variant dummy. This intercept contains two components, one is the unobservable random component of the error residuals and the remaining component of the error residuals which are normally distributed. Often, we have to choose between random-effect and fixed-effect models. Both models give different results if the number of cross-sectional elements is greater than a series of periods. Furthermore, the random-effects model can provide biased results if the error term is correlated with the regressors of the model. In such a scenario, the fixed effects model is superior. It is pertinent to mention that, even when the estimates from a random effects model are valid, the fixed effects estimator still provides reliable estimates (Johnston and DiNardo, 1972). While both techniques are used in the current study, the Hausman test is used to choose the better estimates.

5. Results and Discussion

First, we have employed the cross-sectional dependence tests proposed by Pesaran, Friedman, and Frees to test the null hypothesis of cross-sectional independence (Also reported by Baltagi, 2005). The results of the test are reported in Table 3. Probability values (P-value) from both Pesaran and Friedman are less than 0.1, indicating the rejection of the null hypothesis. Also, the Frees test statistic 0.61 is larger than the critical value 0.213 with at least α=0.01. Hence, we conclude the presence of cross-sectional dependence in the model. See appendix 2b for the results of the panel unit root test. The results indicate the mixed order of cointegration of the modeled variables.

Table 3. Results of cross-sectional dependence tests

	Pesaran	Friedman	Frees
Test value	-2.136	16.88	0.61
P Value/Critical value	0.032	0.004	0.213

5.1. Fixed effects and Random effects

First, we have calculated correlation among the variables of the model (see table 4). The results show that GVC participation, foreign value-added, and domestic value-added indices have a positive correlation with CO2 emissions. Urbanization and GDP per capita also have a positive correlation with emissions.

Table 4. Matrix of correlations

Variables	COE	GVC index	FVA index	DVX index	GDP	Urbanization
COE	1.000					
GVC index	0.477	1.000				
FVA index	0.430	0.798	1.000			
DVX index	0.085	0.340	-0.296	1.000		
GDP	0.837	0.323	0.506	-0.277	1.000	
Urbanization	0.637	0.398	0.175	0.357	0.372	1.000

Source: Authors' calculations

At the first stage, we have estimated the impact of GVC participation index on CO2 emissions by using random effects and fixed effects models with Driscoll and Kraay standard errors. The results of random effects and fixed effects models are reported in Tables 5 and 6, respectively. Conforming to the theoretical framework, an increase in GVC participation leads to an increase in CO2 emissions (Antras, 2019), which is exhibited in all of the five equations estimated by both fixed-effects and the random-effects model. The results also confirm the Environmental Kuznets Curve (EKC) hypothesis since the coefficient of the squared term of GDP per capita is negative. The results are consistent and robust in both fixed effects and random effects. The findings show that the GVC participation is resulting in pollution in the selected panel of countries through the channel of pollution haven hypothesis. These findings are similar to that of Zhang et al. (2021) and Duan et al., (2021). Impacts of the financial crisis of 2008 and WTO is also controlled in the models. The coefficient of the financial crisis dummy is statistically significant and negative, which indicates that pollution emissions fell as a result of adverse shock to GVCs. Moreover, the positive sign of the WTO dummy indicates the significant role of WTO in expanding international trade flows and the resulting pollution emissions. Here, we can anticipate the role WTO can play in achieving Sustainable Development Goals (SDGs) by promoting the inter-country transfer of environmental-friendly technologies. The results of the Hausman test of the model from the first stage are reported in Table 7.

Table 5. The results of random effects model (Stage 1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	COE	COE	COE	COE	COE

GVC Index	1.635***	0.630***	0.633***	0.221*	0.255**
	(0.177)	(0.152)	(0.135)	(0.128)	(0.129)
GDP		0.000402***	0.000717***	0.000456***	0.000461***
		(3.12e-05)	(5.12e-05)	(5.17e-05)	(5.15e-05)
GDP^2			-3.19e-08***	-2.12e-08***	-2.15e-08***
			(4.41e-09)	(3.90e-09)	(3.88e-09)
Urbanization				0.0487***	0.0481***
				(0.00539)	(0.00538)
Financial crisis 2008				-0.104*	-0.103*
				(0.0600)	(0.0597)
WTO					0.142*
					(0.0817)
Constant	-6.489***	-3.741***	-4.110***	-3.435***	-3.557***
	(0.701)	(0.575)	(0.546)	(0.466)	(0.469)
Observations	203	203	203	203	203
Number of id	7	7	7	7	7

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6. The results of fixed effects model (Stage 1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	COE	COE	COE	COE	COE
GVC index	1.622***	0.584***	0.605***	0.208	0.243*
	(0.178)	(0.153)	(0.136)	(0.129)	(0.130)
GDP		0.000418***	0.000730***	0.000467***	0.000473***
		(3.22e-05)	(5.17e-05)	(5.35e-05)	(5.34e-05)
GDP^2			-3.21e-08***	-2.14e-08***	-2.17e-08***
			(4.41e-09)	(3.95e-09)	(3.93e-09)
Urbanization				0.0478***	0.0471***
				(0.00556)	(0.00555)
Financial crisis 2008				-0.103*	-0.102*
				(0.0603)	(0.0600)
WTO					0.143*
					(0.0822)
Constant	-6.442***	-3.611***	-4.034***	-3.386***	-3.510***
	(0.643)	(0.520)	(0.466)	(0.417)	(0.421)
Observations	203	203	203	203	203
R-squared	0.298	0.624	0.705	0.790	0.793
Number of id	7	7	7	7	7

Robust standard errors in parentheses

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

Table 7. The results of Hausman test

Hausman test	(1)	(2)	(3)	(4)	(5)
P-value	0.573	0.0650	0.160	0.852	0.925
Decision	Random effects	Fixed effects	Random effects	Random effects	Random effects

Source: Authors' estimates

At the second stage, we have analyzed the disaggregated impact of GVC participation by putting the foreign value-added index as a focused explanatory variable. The results of random effects and fixed effects are presented in Tables 8 and 9, respectively. The outcome indicates that an increase in backward GVC participation leads to an increase in CO2 emissions, hence confirming the pollution haven hypothesis in the selected region, as discussed in the theoretical framework. This hypothesis claims that developed countries transfer the pollution-intensive activities towards the developing countries (Antras, 2019). The backward GVC participation is also known as the foreign value-added embodied in a particular country's exports. Hence, it is found that the expansion of participation in global production networks in terms of backward participation leads to environmental damage in the selected countries. The effects are also controlled by incorporating the dummy variables of the global financial crisis and WTO. The results of the Hausman test indicate that random effects estimates are more reliable than the fixed effect estimates (see Table 10). At the third stage, the impact of domestic value-added on CO2 emissions is analyzed. To confirm any differential impacts of foreign and domestic value-added on CO2 emissions. We have used these two disaggregated measures. The results of random effects and fixed effects of this stage are presented in Table 11 and 12 respectively. The coefficient of the domestic value-added index is significant and positive which indicates that an increase in domestic value-added in other countries' exports or forward linkages of GVC leads to environmental degradation. This result is aligned with the outcomes of Zhang et al. (2017). Coefficients of both aggregated and disaggregated indicators confirm the pollution-intensive nature of GVC participation in the selected panel of countries. These results also indicate that there is a significant difference in GVC-CO2 emissions linkages before and after the Doha agreement of WTO.

Table 8: The results of random effects model (Stage 2)

	(1)	(2)	(3)	(4)	(5)

VARIABLES	COE	COE	COE	COE	COE
FVA	0.860***	0.424***	0.333***	0.00306	-0.0332
	(0.159)	(0.110)	(0.102)	(0.0914)	(0.0896)
GDP		0.000445***	0.000740***	0.000454***	0.000392***
		(2.79e-05)	(5.22e-05)	(5.22e-05)	(5.38e-05)
GDP^2			-2.92e-08***	-2.02e-08***	-1.68e-08***
			(4.56e-09)	(3.89e-09)	(3.90e-09)
Urbanization				0.0523***	0.0447***
				(0.00537)	(0.00565)
Financial crisis 2008				-0.0818	-0.116**
				(0.0593)	(0.0585)
WTO					0.160***
					(0.0453)
Constant	-2.809***	-2.658***	-2.764***	-2.749***	-2.451***
	(0.538)	(0.415)	(0.415)	(0.315)	(0.322)
Observations	203	203	203	203	203
Number of id	7	7	7	7	7

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 9. The results of fixed effects model (Stage 2)

VARIABLES	(1) COE	(2) COE	(3) COE	(4) COE	(5) COE
FVA	0.888***	0.452***	0.352***	0.0125	-0.0292
	(0.165)	(0.111)	(0.103)	(0.0950)	(0.0931)
GDP		0.000454***	0.000748***	0.000464***	0.000397***
		(2.82e-05)	(5.23e-05)	(5.40e-05)	(5.58e-05)
GDP^2			-2.93e-08***	-2.04e-08***	-1.69e-08***
			(4.54e-09)	(3.93e-09)	(3.95e-09)
Urbanization				0.0511***	0.0439***
				(0.00562)	(0.00584)
Financial crisis				-0.0827	-0.116**
				(0.0597)	(0.0588)
WTO					0.160***
					(0.0460)
Constant	-2.882***	-2.748***	-2.830***	-2.760***	-2.451***
	(0.426)	(0.280)	(0.255)	(0.216)	(0.228)
Observations	203	203	203	203	203
R-squared	0.130	0.627	0.693	0.787	0.800
Number of id	7	7	7	7	7

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 10. The results of Hausman test

Hausman test	(1)	(2)	(3)	(4)	(5)
P-value	0.527	0.163	0.0182	0.949	0.926
Decision	Random effects	Random effects	Fixed effects	Random effects	Random effects

Table 11. The results of random effects model (Stage 3)

VARIABLES	(1) COE	(2) COE	(3) COE	(4) COE	(5) COE
DVX	1.139***	0.349***	0.603***	0.268***	0.172*
	(0.127)	(0.116)	(0.107)	(0.1000)	(0.104)
GDP		0.000396***	0.000744***	0.000472***	0.000414***
		(3.21e-05)	(4.94e-05)	(5.14e-05)	(5.47e-05)
GDP^2			-3.95e-08***	-2.50e-08***	-2.04e-08***
			(4.72e-09)	(4.24e-09)	(4.48e-09)
Urbanization				0.0480***	0.0428***
				(0.00521)	(0.00545)
Financial crisis 2008				-0.115*	-0.134**
				(0.0598)	(0.0591)
WTO					0.132***
					(0.0474)
Constant	-4.073***	-2.523***	-3.651***	-3.435***	-3.005***
	(0.536)	(0.362)	(0.355)	(0.318)	(0.350)
Observations	203	203	203	203	203
Number of id	7	7	7	7	7

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 12. The results of fixed effects model (Stage 3)

VARIABLES	(1) COE	(2) COE	(3) COE	(4) COE	(5) COE
DVX	1.145***	0.192	0.499***	0.236**	0.139
	(0.128)	(0.124)	(0.113)	(0.104)	(0.107)
GDP		0.000446***	0.000767***	0.000479***	0.000416***
		(3.64e-05)	(5.01e-05)	(5.36e-05)	(5.69e-05)

GDP^2			-3.85e-08***	-2.46e-08***	-1.98e-08***
			(4.67e-09)	(4.28e-09)	(4.51e-09)
Urbanization				0.0473***	0.0418***
				(0.00536)	(0.00559)
Financial crisis 2008				-0.111*	-0.131**
				(0.0599)	(0.0591)
WTO					0.139***
					(0.0478)
Constant	-4.094***	-2.152***	-3.392***	-3.339***	-2.896***
	(0.392)	(0.335)	(0.326)	(0.282)	(0.316)
Observations	203	203	203	203	203
R-squared	0.291	0.601	0.704	0.793	0.802
Number of id	7	7	7	7	7

Robust standard errors in parentheses

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

Table 13. The results of Hausman test

Hausman test	(1)	(2)	(3)	(4)	(5)
P-value	0.599	0.020	0.035	0.648	0.571
Decision	Random effects	Fixed effects	Fixed effects	Random effects	Random effects

Conclusion and Policy Recommendations

The rapid rise in the globalization of production processes, knowledge spillovers, grave environmental concerns, and sustainable development goals have attracted researchers and policymakers to explore the causes and consequences of these transformations. The developing countries such as SAARC economies are considered highly vulnerable to climatic changes. This study contributes a comprehensive empirical analysis to examine the role of participation in global value chains in determining CO2 emissions in SAARC economies. The impact of disaggregated components of the global value chains participation such as forward GVC participation and backward GVC participation on CO2 emissions is also examined. This study also captures the impact of the global financial crisis of 2008 and the emergence of WTO on GVC-CO2 emissions relationship. The empirical findings of the analysis show that expansion of global value chains participation leads to increase in CO2 emissions. It is also found that both backward and forward GVC participation cause increase in the CO2 emissions. Urbanization has increasing impact on the emissions. Moreover, EKC hypothesis is confirmed. . Furthermore, the results indicate the positive and significant impact of accession to the WTO on CO2 emissions.

Based on the findings of the analysis, the selected SAARC countries should adopt and implement policies aiming at decoupling the environmental pollutions from both forward and backward GVC participation to promote their environmental quality. To do so, the selected countries should promote the transfer of environmental-friendly technologies through GVC participation, impose carbon taxes, and transform their production processes by adopting the renewable energy sources. Furthermore, WTO should play a defining role in promoting the flows of clean technologies to transform the global value chains into green global value chains. Moreover, these countries should pursue growth-enhancing policies to improve the environment quality. Finally,, the selected countries are recommended to discourage massive urbanization and revisit their urbanization policies with a focus on sustainable and smart cities to combat the CO2 emissions and the challenges of climate change. Decentralization of administrative units and industrialization throughout the countries, rather than capital cities only, with proper planning, can also mitigate the environmental degradation in the populous SAARC countries.

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Appendix

Fig. A.1 DVA and FVA by Bangladesh

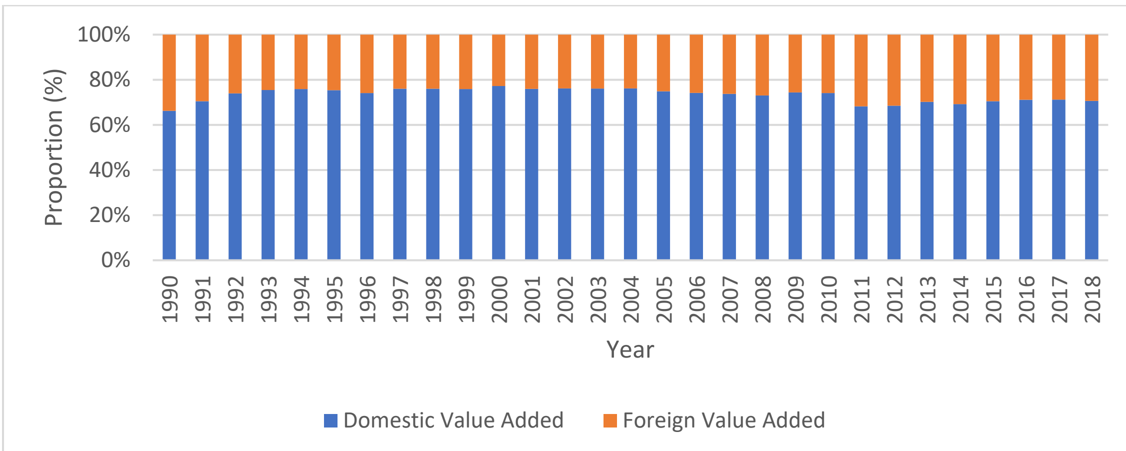

Fig. A.2 DVA and FVA by Sri lanka

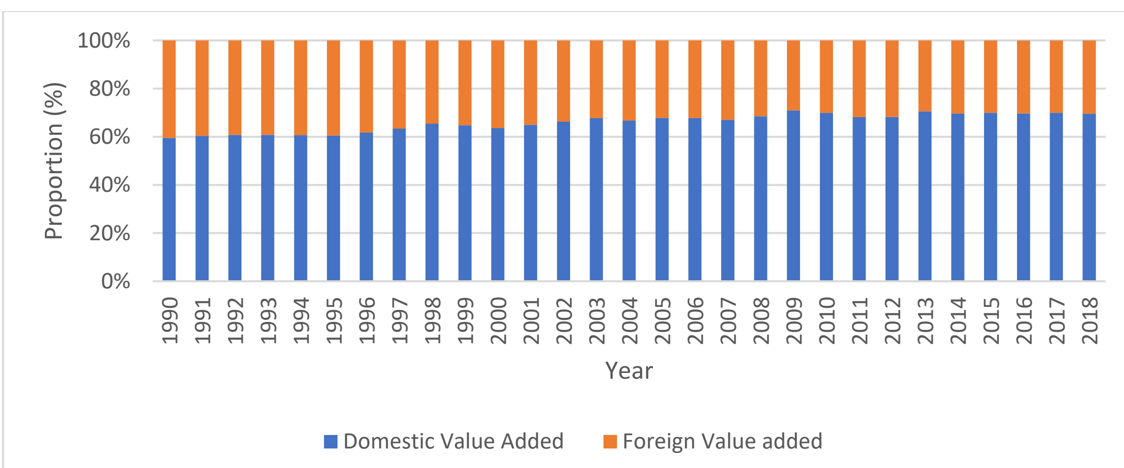

Fig. A.3 DVA and FVA by Nepal

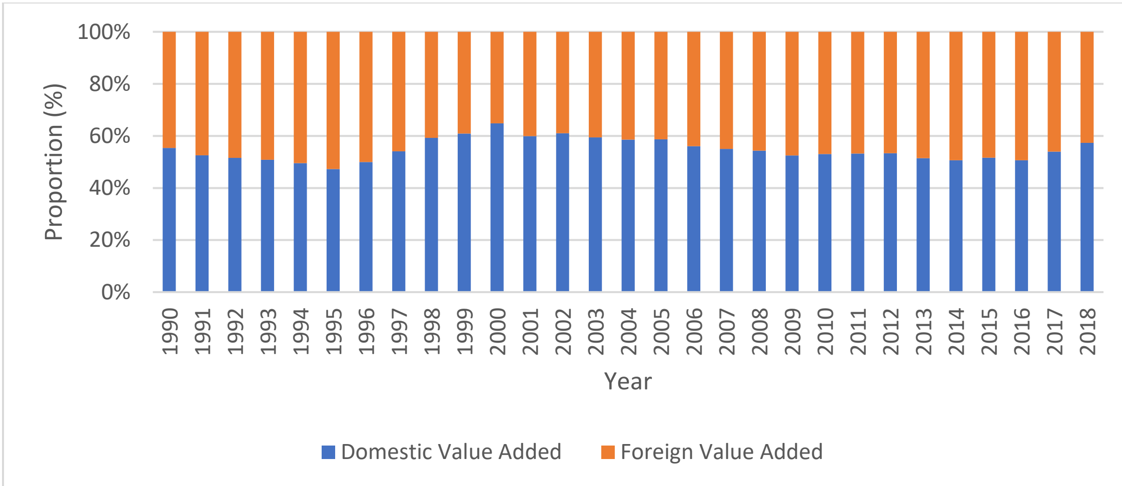

Fig. A.4 DVA and FVA by Bhutan

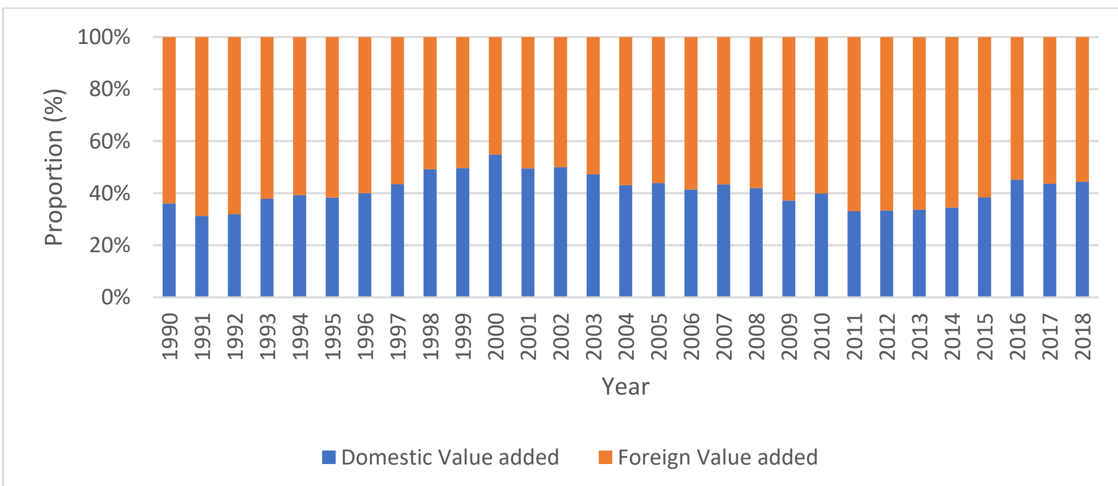

Table A.1. List of countries included in sample

India	Bangladesh	Pakistan	Maldives
Sri Lanka	Nepal	Bhutan	

Table A.2. List of countries included in sample

Series	CADF P-value		
	I (0)	I (1)	Outcome
COE	0.688	0.011	I (1)
GVCP	0.578	0.000	I (1)
GDPC	0.353	0.051	I (1)
GDPCSQ	0.337	0.019	I (1)
URBAN	0.675	0.071	I (1)

FVA	0.034	-	I (0)
DVX	0.223	0.000	I (1)