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Synergetic Impact of Institutional Quality, Foreign Direct Investment, Urban Population Growth and Trade on CO2 Emission: Selective Countries of South Asian

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Abstract
This research examines the relationships within CO2, Institutional quality, foreign direct investment (FDI), urban population growth and Trade in India, Pakistan, Bhutan, Afghanistan, and Bangladesh, five countries in south Asia. ARDL Autoregressive distributed lag model outcomes suggest, factors effecting environmental quality in all countries move in unison over the long term (co-integration). The environmental Kuznets curve hypothesis EKC is also supported by the results. Additionally Institutional quality seems to have negative influence on environmental quality while foreign direct investment (FDI), urban population growth and Trade positively influenced CO2 emission. ARDL observations demonstrate, there is a strong correlation among CO2 emission and Institutional quality, foreign direct investment, urban population growth and Trade.
Keywords: Panel autoregressive distributive lag PARDL, urban population growth (URB), institutional quality index (IQ), foreign direct investment (FDI), Trade (TRD)

1. Introduction

In recent decades, the relationship between environmental sustainability and economic development has received a lot of attention; particularly in light of growing global is concerned about climate change (Raihan et al., 2022; Parveen et al., 2024) The purpose of this research is to investigate the complex interactions that occur when commerce, urban population expansion, foreign direct investment (FDI), and institutional quality all affect carbon dioxide (CO2) emissions. South Asian nations are the subject of a special inquiry because of the region's rapid economic growth, urbanization, and serious environmental issues (Fang et al., 2022; Amin et al., 2024; Sadia Bint Raza et al., 2024).

South Asia, which includes nations like Bangladesh, India, Pakistan, Bhutan, and Bangladesh, is going through a rapid economic development phase. Numerous causes, such as significant inflows of foreign direct investment, growing urban populations, and an increase in trade activity, are responsible for this expansion. But these advancements in development come with a price in terms of the environment, most notably an increase in CO2 emissions. For the purpose of developing sustainable development policies, it is essential to comprehend the factors that influence CO2 emissions in this particular setting (Zubair et al., 2024; Song et al., 2024). The influence of institutional quality, which includes legality, regulatory frameworks, and governance systems, on environmental results is significant(Costantiello & Leogrande, 2024; Shahbaz et al., 2023). Robust establishments possess the ability to uphold environmental policies, encourage eco-friendly behaviors, and draw in green capital. On the other hand, inadequate institutional frameworks could result in environmental deterioration because of a lack of regulatory capture and enforcement(Afshan & Yaqoob, 2023; Koirala, 2019; Rabbia Syed, Sehrish Arshad, Saif Ur Rahman, 2024).

South Asia's economy continues to expand predominantly as a result of FDI(Agrawal, 2000; Sahoo & Sethi, 2023; Sahoo, 2006). Although it brings in money, technology, and management skills, its effects on the environment are controversial. According to the pollution haven hypothesis, foreign direct investment (FDI) could result in increased emissions if companies transfer their polluting sectors to nations with less stringent environmental laws. On the other hand, the pollution halo hypothesis contends that FDI can improve environmental quality by facilitating the adoption of greener practices and technology (Singhania & Saini, 2021; Saeed et al., 2024; Shen et al., 2024).

Another important aspect affecting CO2 emissions is urbanization (Rehman & Rehman, 2022; Xu et al., 2024). Increased energy use, the demand for transit, and industrial activity are all linked to South Asian cities' rapid urban population growth, which raises CO2 emissions (Ridwan et al., 2024). Urban settings, however, also offer chances to use sustainable techniques, like effective waste management, green construction, and public transit (Hegazy et al., 2024; Huang et al., 2024; Arshad et al., 2024). Trade liberalization has a number of ways to affect CO2 emissions(Wang et al., 2024). It may result in more industrial production and economic activity, which could raise emissions(Kozul-Wright & Fortunato, 2012). Conversely, commerce may help ecologically favorable habits and technologies spread, which could lower carbon emissions. Thus, the overall impact of trade on CO2 emissions is still up for empirical investigation(Zhang & Shang, 2022; J. Saeed et al., 2024; Maqsood1 et al., 2023).

The purpose of this research is to empirically examine how trade, FDI, urban population growth, and institutional quality affect CO2 emissions in South Asian nations. It specifically aims to:

- Analyze the connection between CO2 emissions and institutional quality.
- Examine how foreign direct investment affects the environment in South Asia.
- Analyze how rising urban populations affect CO2 emissions.
- Examine how trade affects the region's CO2 emissions.

It is imperative for policymakers to comprehend the factors that influence carbon emissions in South Asia if they are to strike a balance between economic growth and environmental sustainability. The results of this study will shed light on how trade policies, urbanization, investment patterns, and institutional frameworks may all be coordinated to reduce CO2 emissions and advance sustainable development. The study adds to the wider conversation on sustainable development by emphasizing the unique dynamics at work in a region that is developing quickly and is confronting major environmental issues.

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The format of the paper is as follows: The relevant research on the factors influencing CO2 emissions is reviewed in Section 2. The analysis's methodology and data sources are described in Section 3. The empirical data are presented and discussed in Section 4. Recommendations for policies and directions for further research are included in Section 5.

2. Literature Review

2.1. Institutional Quality and CO2 Emissions

The influence of institutional quality, encompassing governance efficacy, regulatory quality, and rule of law, on environmental results is significant. Robust establishments possess the ability to uphold ecological policies, encourage enduring behaviours, and expedite the integration of eco-friendly innovations. (Eskeland & Harrison, 2003) discovered a correlation between reduced pollution levels in developing nations and improved governance and regulatory quality. Strong institutions, they said, can efficiently implement environmental rules, cutting down on carbon dioxide emissions. In their study of the relationship between institutional quality and environmental performance,(Cole et al., 2006) discovered that nations with higher levels of corruption also typically have higher levels of pollution, including CO2 emissions. This is due to the fact that corruption makes it more difficult to enforce environmental laws (Minhas et al., 2024; Abro et al., 2024; Shahid, 2024).

(Murshed et al., 2022) investigation of the relationship between institutional quality and CO2 emissions in South Asian nations came to the conclusion that better institutional quality can lower CO2 emissions considerably by boosting the efficacy of regulations and encouraging sustainable development.

2.2. Foreign Direct Investment (FDI) and CO2 Emissions

There are two opposing views on the complex relationship between FDI and CO2 emissions: the pollution halo hypothesis and the pollution haven hypothesis: According to the Pollution Haven hypothesis, foreign direct investment (FDI) could result in increased emissions if multinational companies shift their pollution-intensive businesses to nations with less stringent environmental laws. (Cole & Elliott, 2005; Irfan et al., 2023; Shahid, 2023) discovered evidence in favor of the pollution haven theory, demonstrating that foreign direct investment (FDI) in industries with high levels of pollution can result in increased carbon dioxide emissions in host nations with lax environmental laws. Conflicts According to the Halo Hypothesis, foreign direct investment (FDI) can improve environmental quality by transferring cleaner technology and practices. According to (Birdsall & Wheeler, 1993), FDI could enhance environmental performance by introducing cutting-edge technologies and improved emission-reduction strategies for management. (Zarsky, 1999) discovered conflicting data, indicating that although foreign direct investment (FDI) raises emissions in certain industries, it can also improve environmental practices in other ones.

2.3. Urban Population Growth and CO2 Emissions

Urbanization has a major impact on CO2 emissions because it increases energy consumption, the need for transportation, and industrial activity. Urban population growth and CO2 emissions have a positive correlation, according to (Marcotullio et al., 2014) research, especially in emerging nations where cities are expanding quickly. They emphasized that in order to lessen the negative effects of urbanization on the environment, sustainable urban planning is essential. When (Parikh & Shukla, 1995; Shahid, 2024c) examined how urbanization affected CO2 emissions in India, they discovered that because of increased energy use and transportation, emissions from urban areas are disproportionately higher. (Liddle, 2013; Shahid, 2024b) offered a thorough analysis of the relationship between urbanization and emissions, emphasizing that an urban area's density and structure are key factors in determining its environmental impact. The per capita CO2 emissions in high-density urban regions with effective public transport networks are generally lower.

2.4. Trade and CO2 Emissions

Trade liberalization may have an effect on CO2 emissions by boosting industrial output and economic activity or by promoting the use of eco-friendly practices and technologies. According to (Antweiler et al., 2001; Shahid et al., 2023) analysis of trade's effects on pollution, trade can result in emissions increases or decreases based on how scale, composition, and technique effects are balanced. They came to the conclusion that if trade liberalization encourages the use of greener technologies, it may lower CO2 emissions. (Frankel & Rose, 2005) looked at the relationship between trade and the environmental Kuznets curve. They discovered that while trade openness can initially result in increased emissions, it can also gradually contribute to lower emissions when nations adopt tougher environmental rules and grow wealthier. A theoretical framework for understanding the relationship between trade and the environment was presented by (Copeland & Taylor, 2004)They pointed out that the interplay of economic growth, regulatory frameworks, and technology advancement determines how trade affects CO2 emissions. The empirical literature shows that trade, FDI, urban population expansion, and institutional quality all have a major impact on CO2 emissions. Reducing emissions and enforcing environmental regulations effectively depend on robust institutions. FDI has a mixed effect on CO2 emissions, with both possible negative and positive outcomes. Though this effect can be lessened by sustainable urban planning, urbanization normally results in higher emissions. Trade has an impact on CO2 emissions through a variety of mechanisms, and the overall outcome is determined by how much economic activity and how much greener technology are adopted.

3. Methodology

The current research was conducted using information from the five South Asian nations like Pakistan, India, Bhutan, Afghanistan, and Bangladesh. In the current study, independent and dependent variables are both used. For study the independent factors are foreign direct investment, institutional quality, trade and urban population growth. The dependent variable is CO2 emission. Annual data on each of these characteristics have been collected for the South Asian nations for the 20 years between 2003 and 2023. Both the World Development Indicators (WDI) and the World Bank have databases from which the data was gathered. Each of these variables, along with an explanation of each measurement unit and its source, are listed in the table below.

Table 1

Symbols	Variables	Measurement	Data Resources
CO2	Carbon dioxide emission	CO2 emissions from transport (% of total fuel combustion),CO2 emissions from manufacturing industries and construction (% of total fuel combustion), CO2 emissions from electricity and heat production, total (% of total fuel combustion), CO2 emissions from other sectors, excluding residential buildings and commercial and public services (% of total fuel combustion), CO2 emissions from residential buildings and commercial and public services (% of total fuel combustion)	World bank
FDI	Foreign direct investment	Foreign direct investment, net inflows (% of GDP)	WDI
IQ	Institutional Quality	Measure through six selected indicators (Control of Corruption: Percentile Rank, Government Effectiveness: Percentile Rank, Political Stability and Absence of Violence/Terrorism: Percentile Rank, Regulatory Quality: Percentile Rank, Rule of Law: Percentile Rank, Voice and Accountability: Percentile Rank.)	WDI
TRD	Trade	Trade (% of GDP)	World bank
URB	Urban population growth	Urban population growth (annual %)	World bank

3.1. Descriptive Analysis

Table 2 offers descriptive information for the factors or variables. The means, medians, maximums, and minimums of each series are presented in the table of statistics.

Table 2

	CO2	FDI	IQ	TRD	URB
Mean	0.710307	-0.158012	0.792481	3.538408	1.143784
Median	0.629972	-0.128411	0.808574	3.573411	1.113201
Maximum	1.855882	1.843972	1.155245	4.758318	2.073606
Minimum	0.043730	-2.782032	0.419708	1.835369	0.576477
Std. Dev.	0.497901	0.918016	0.168606	0.742697	0.294875
Skewness	0.662932	-0.549258	-0.216770	-0.398848	0.625055
Kurtosis	2.456065	3.489882	2.217357	2.648133	3.340146
Jarque-Bera	8.557417	6.027998	3.335358	3.167211	6.993647
Probability	0.013861	0.049095	0.188684	0.205234	0.030293
Sum	71.03070	-15.80118	79.24811	353.8408	114.3784
Sum Sq. Dev.	24.54264	83.43260	2.814367	54.60827	8.608200
Observations	100	100	100	100	100

Table 3: Correlation matrix of variables

	CO2	FDI	IQ	TRD	URB
CO2	1				
FDI	0.213470	1			
IQ	-0.1860768	0.0912608	1		
TRD	0.360270	0.1796255	0.094189	1	
URB	-0.745431	-0.176665	0.224893	-0.1897440	1

3.2. Model Specification

Equation (1) below can be used to simulate the causal connection between emissions of carbon dioxide, Institutional quality, foreign direct investment (FDI), urban population growth and Trade in accordance with environmental Kuznets curve theory. We comply with the methods used in earlier research, (Halicioglu, 2009; Jalil & Mahmud, 2009; Pao & Tsai, 2011)), where the model used is

$$CO_{2it} = \alpha_0 = \alpha_1 FDI_{it} + \alpha_2 IQ_{it} + \alpha_3 URB_{it} + \alpha_4 TRD_{it} + \mu_{it}$$

Where CO2 is equal to environmental quality or CO2 emissions, FDI used for foreign direct investment, IQ stands for Institutional, URB for urbanization, TRD for trade and error term is denoted by μ.

3.3. Testing for co-integration

We proceed by determining if the variables are co-integrated, or whether they move together across time. To choose the best strategy for testing co-integration, we must first determine the sequence in which each series is integrated. We therefore use the most modern testing with ARDL (Autoregressive Distributed Lags) methodology. This technique of co-integration was offered by (Pesaran & Shin, 1995) then pushed up by (Pesaran et al., 2001). ARDL modeling of co-integration test among the variables is new, despite the fact that they have long been utilized in other contexts. For large sample sizes, the critical values given. While (Narayan, 2004; Narayan, 2003, 2005) Offer crucial values that are compatible with samples with small sizes. Some other co-integration methods exist as well, including Engel's 1987 methodology & fully modified OLS (ordinary least squares) methods that were constructed by

(Phillips & Hansen, 1990). Due to some helpful advantages that are built into it, ARDL has been employed more recently. One of the main benefits of this method is that it may be used for sequences with I(0), I(1), or Partially co-integrated (Adom et al., 2012; Wolde-Rufael, 2010). The ability to simultaneously create short- and long-term estimates is another benefit. Additionally, The Engle Granger method prevents endogeneity problems and a failure to assess the theory on the anticipated variables over a long period of time (Halicioglu, 2009). The data provided was acquired for India, Pakistan, Bangladesh, Bhutan, and Afghanistan between the years of 2003 and 2023 from the World Development Indicators (WDI) online data base. The equation of ARDL formula as the model can be written as:

$$\Delta CO_{it} = \alpha_0 + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta FDI_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta IQ_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta URB_{j,t-i} + \sum_{i=1}^{m} \beta_{ik}\, \Delta TRD_{j,t-i} + \varphi_1 CO_{t-1} + \varphi_2 FDI_{t-1} + \varphi_3 IQ_{t-1} + \varphi_4 URB_{t-1} + \varphi_5 TRD_{t-1} + e_{it}$$

Ik and It are respectively country and time fixed effects, with I=1,....,N for each country and t=1,.....,T for each period. It displays the projected residuals.

$$\Delta CO_{it} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta\, FDI_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta\, IQ_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta URB_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta TRD_{j,t-i} + e_{it}$$

If there is a co-integration, next step of ARDL process holds the long-run ARDL equation as follows:

$$CO_{it} = \beta_0 + \sum_{i=0}^{p} \beta_{ik}\, CO_{2t-i} + \sum_{i=1}^{q} \beta_{ik}\, FDI_{t-i} + \sum_{i=1}^{r} \beta_{ik}\, IQ_{t-i} + \sum_{i=0}^{s} \beta_{ik}\, URB_{t-i} + \sum_{i=0}^{t} \beta_{ik}\, TRD_{t-i} + e_t$$

The ARDL method, also referred to as the error-correction model, short-run estimation is calculated using the equation below.

$$CO_{it} = \delta_0 + \sum_{i=0}^{p} \delta_{ik} \Delta\, CO_{2t-i} + \sum_{i=1}^{q} \delta_{ik} \Delta\, FDI_{t-i} + \sum_{i=0}^{r} \delta_{ik}\, \Delta IQ_{t-i} + \sum_{i=0}^{s} \delta_{ik}\, \Delta URB_{t-i} + \sum_{i=0}^{t} \delta_{ik}\, \Delta TRD_{t-i} + \lambda \mathrm{ECM}_{t-1} + e_{it}$$

3.4. Unit Root Test

Tables 5 and 6 show the results of unit root tests, which showed that there was a mix of I(0) and I(1), that FDI is stationary at level (at trend and intercept), and that maximum period remains stationary when taking the first difference. So we use ARDL approach to examine the relationship of variables.

Table 4: Unit Root Test at Level

		Level			
		With Intercept		With Trend & Intercept	
Variables		Statistics	P Value	Statistics	P Value
CO2	LLC	2.67803	0.9963	-0.70999	0.2389
	IPS	3.51775	0.9998	0.40494	0.6572
FDI	LLC	-1.15569	0.1239	-2.31122	0.0104
	IPS	-1.59830	0.0550	-1.90675	0.0283
IQ	LLC	0.70397	0.7593	-0.17002	0.4325
	IPS	1.10942	0.8664	0.33087	0.6269
URB	LLC	-1.37692	0.0842	-1.15752	0.1235
	IPS	-1.62654	0.0519	-0.71041	0.2387
TRD	LLC	-0.90001	0.1841	-0.17083	0.4322
	IPS	1.19025	0.8830	0.08693	0.5346

Table 5: Unit Root Test at Level

		1st Difference			
		With Intercept		With Trend & Intercept	
Variables		Statistics	P-Value	Statistics	P-Value
CO2	LLC	-2.68994	0.0036	-2.0033	0.0227
	IPS	-2.29191	0.0110	-1.35365	0.0879
FDI	LLC	-5.48345	0.0090	-4.33798	0.0000
	IPS	-5.79318	0.0000	-4.66360	0.0000
IQ	LLC	-5.72014	0.0000	-3.87616	0.0001
	IPS	-5.13927	0.0000	--3.86906	0.0001
URB	LLC	-1.56175	0.0592	-1.02041	0.1538
	IPS	-5.54894	0.0000	-4.61851	0.0000
TRD	LLC	-3.61948	0.0001	-4.40250	0.0000
	IPS	-2.62391	0.0043	-2.19356	0.0141

The results of the unit root test indicate that some of the variables have statistically stationary at the first difference and some of them are at level. So these results fulfill the condition of ARDL. So we use ARDL to analyze the relation of variables.

Table 6: ARDL results

Selected Model: ARDL(1, 3, 3, 3, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
	Long Run Equation			
FDI	9.556789	0.774690	12.33628	0.0000
IQ	-31.05740	2.254538	-13.77550	0.0000
TRD	2.674006	0.181735	14.71377	0.0000
URB	16.05229	1.206452	13.30537	0.0000
	Short Run Equation			
COINTEQ01	-0.019808	0.010600	-1.868725	0.0711
D(FDI)	-0.165390	0.078482	-2.107357	0.0433
D(FDI(-1))	-0.103341	0.060150	-1.718050	0.0958
D(FDI(-2))	-0.109083	0.068984	-1.581277	0.1240
D(IQ)	0.593756	0.430094	1.380527	0.1773
D(IQ(-1))	0.232309	0.330739	0.702393	0.4877
D(IQ(-2))	0.346421	0.144693	2.394180	0.0229
D(TRD)	-831.0886	831.3107	-0.999733	0.3252
D(TRD(-1))	1841.072	1840.873	1.000109	0.3250
D(TRD(-2))	-1013.947	1013.927	-1.000020	0.3250
D(URB)	-0.222331	0.549588	-0.404542	0.6886
D(URB(-1))	-0.590358	0.609445	-0.968681	0.3402
D(URB(-2))	0.825822	0.401915	2.054718	0.0484
Root MSE	0.013437	Mean dependent var		0.033115
S.D. dependent var	0.050993	S.E. of regression		0.024134
Akaike info criterion	-4.405736	Sum squared resid		0.018056
Schwarz criterion	-2.608168	Log likelihood		289.2868
Hannan-Quinn criter.	-3.678228			

Panel ARDL results indicate that at 5 percent level, Trade (TRD) has become considerable or stationary and positively influenced CO2 emissions. As previously researched by (Ghazouani & Maktouf, 2024) Which means that renewable energy consumption directly affect environmental quality because according to this study as trade increases CO2 emission will also be increased and vice versa.as studied earlier by (Vidya, 2024). Foreign direct investments (FDI) have significant at 5% level but positive impact on CO2 emissions. As it is studied earlier by (Salahodjaev & Isaeva, 2024). This means foreign direct investments favorably affects environmental quality because according to this study as FDI increases CO2 emission will also be increased and vice versa. Institutional quality (IQ) has significant at 5 % level but negative impact on CO2 emissions. IQ has long run negative effect on CO2 emissions as studied earlier by (Ogede et al., 2024). This means Institutional quality inversely affect environmental quality because according to this study as IQ increases CO2 emission will also be decreased and vice versa. As it is studied earlier by (Ogede et al., 2024). Urbanization URB has significant at 5% level and positive impact on CO2 emission as studied earlier by (Zhai & Kong, 2024). It means as IQ improves CO2 omits from environment. Environmental Quality will be improved. As it is studied earlier by (Chen et al., 2023).

4. Conclusion

Assessing the effects of Institutional quality, foreign direct investment (FDI), urban population growth and Trade on CO2 is the goal of the research presented in this article, in India, Pakistan, Afghanistan, Bangladesh, and Bhutan, five South Asian nations, over the years 2003 to 2023. Levin, Lin, and Chu (1992) and Im, Pesaran, Shin (IPS) unit root tests reveal the variables are stationary at the first difference or some levels. The FDI, URB, TRD and IQ are examined for their long- and short-term effects on CO2 emissions using ARDL methodology. Panel ARDL finding reveal that urbanization is stationary at 5 percent level and positive impact on CO2 emissions. Moreover, foreign direct investments (FDI) have significant at 5% level but positive impact on CO2 emissions. Institutional quality is stationary at 5 percent level but inverse impact on CO2 emissions. TRD has stationary at 5percent level and direct & positive effect on environmental quality or CO2 emission. It's imperative that these nations implement environmental quality-related regulations and policies to cut back on foreign direct investment as it has been demonstrated that the decline in GNP and in foreign direct investment are both influenced by environmental factors. Our study's most important discoveries are that trade has a positive effect on CO2 emissions. It can be stated that increasing trade can further enhance this impact. Additionally, the fact that institutional quality has a negative and significant impact on CO2 emissions highlights the need for government intervention to put in place laws that will support the use of IQ, the use of energy sources, and reduced CO2 emissions in these countries' economy. In light of the findings from analysis, it is recommended institutional quality developed lower environmental quality in five South Asian nations. It demonstrates the necessity of government involvement to put into place laws that support the institutional quality and institutional standards to curb environmental deterioration or CO2 emissions in these nations' economies.

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