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The Effect of Trade Development on Fossil Fuel Consumption in South Asian Countries

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Utilizing the Autoregressive Distributed Lag (ARDL) framework for cointegration, this study performs a comprehensive long and short-run analysis of the connection between trade development and fossil fuel consumption using data from 1980 to 2020. Fossil fuel consumption in Bangladesh and Pakistan is influenced by exports, based on co-integration among the variables. Trade openness is positively significant in Nepal. This is in contrast to Bangladesh, where it is negatively significant. Additionally, the exchange rate employs a positive significance in Bangladesh and India while negative in Nepal. The short-run analysis reveals similar relational dynamics, whereas the exchange rate positively influences Pakistan.

I. INTRODUCTION

Studies have often been carried out on the linear and asymmetric relationship between renewable and nonrenewable energy consumption, environmental dimensions, and economic growth (Ali et al., 2021; Sehar & Khan, 2014). Moreover, most of the research papers discuss and compare energy consumption taking into consideration various economic indicators, mainly GDP, inflation, and foreign direct investment (Gokmenoglu & Sadeghieh, 2019; Kahia et al., 2021). However, fossil fuel consumption and its impact on trade and the economic environment of emerging economies is a significant issue that needs to be reviewed and discussed critically.

Fossil fuel consumption has been at the core of global energy consumption for decades. Fossil fuels, namely coal, oil, and natural gas, are important resources to achieve economic growth and ensure a country's sustainable development goals and trade development (Chen et al., 2021). Fossil fuels have become important to stabilize a country's energy and manufacturing sectors. Fossil energy enables developing countries to use better and smooth energy quality and achieve energy balance (Hao et al., 2016).

Economic environment consist of export and trade openness, reflecting the degree of international trade involvement. These may also be impacted by fossil fuel consumption. Countries that are heavily reliant on fossil fuel imports may have higher trade openness as they need to engage in more international trade to secure their energy needs (Li & Haneklaus, 2022). Moreover, the demand for and supply of fossil fuels can influence exchange rates by

affecting the balance of payments and foreign currency reserves of countries.

Considering Pakistan, Ali et al. (2021) and Sehar and Khan (2014) studied the impact of fossil fuel energy consumption on CO₂ emissions and found both positive and negative impact for different time frames. Moreover, Nnaji et al. (2013) confirmed a positive and significant relationship between CO₂ emissions and fossil fuel consumption. However, Gokmenoglu & Sadeghieh (2019) found that economic growth had a significant negative effect on carbon emissions, while fuel consumption had a positive impact on carbon emissions.

However, fossil fuel energy is not only related to a country's national strategy and energy security; it is mandatory with the integration of advanced technologies at every stage of production (Zhukovskiy et al., 2021). However, no studies have found a link between fossil fuel consumption and trade development nexus. Therefore, this paper seeks to bridge that research gap. Using the Auto-Regressive Distributed Lag (ARDL) approach by Pesaran et al. (2001) and Pesaran & Shin (1997), the period of investigation is from 1980–2020. Therefore, this study contributes to the gap between the causal relationships of these variables.

II. DATA AND METHODOLOGY

A. Data

The research dataset encompasses the period 1980 to 2020, for both dependent and independent variables. The dependent variable, Electricity Production from Fossil Fuels (FC), is gathered from the International Energy Agency

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(IEA), and the independent variables, Exports (EX), Trade Openness (TO), and Exchange Rate (ER), are collected from the World Bank. Together, these variables facilitate an in-depth analysis of the relationship between fossil fuel consumption and trade development in South Asia over a span of four decades, offering invaluable insights into the region's long-term energy and trade trends.

B. Model Specification

The dynamic relationship between fossil fuel consumption and trade development in South Asian nations (Bangladesh, India, Nepal, and Pakistan) is established by integrating the following functional model:

$$FC_t = \delta_0 + \delta_1 EX_t + \delta_2 TO_t + \delta_3 ER_t + \varepsilon_t \quad (1)$$

Here, Trade Openness serves as a proxy for trade development due to its comprehensive nature (Koengkan, 2018). Therefore, it provides a dynamic view of a country's integration into the global trade system, capturing not only the volume of trade but also influencing economic growth and influencing the trade environment Alkhateeb & Mahmood, 2019. Exports and Exchange Rate are treated as control variables. Exports are also a crucial part of trade development, and its influence on fossil fuel consumption is vital to understanding the specific impact of outgoing trade. The Exchange Rate, although not a direct measure of trade development, significantly influences the cost and feasibility of trade and hence, fossil fuel consumption.

C. The Bounds Testing Co-Integration Model

The Bounds Testing Co-Integration Model is to determine the existence of a long-run equilibrium relationship among variables. This approach, based on the Auto Regressive Distributed Lag (ARDL) model introduced by Pesaran et al. (2001) and Pesaran & Shin (1997), is advantageous due to its ability to accommodate a mix of $I(0)$ and $I(1)$ variables.

$$\begin{aligned} \Delta FC = & \delta_0 + \sum_{i=1}^{p1} \delta_{1i} \Delta FC_{t-i} + \sum_{i=0}^{p2} \delta_{2i} \Delta EX_{t-i} \\ & + \sum_{i=0}^{p3} \delta_{3i} \Delta TO_{t-i} + \sum_{i=0}^{p4} \delta_{4i} \Delta ER_{t-i} \\ & + \delta_5 FC_{t-1} + \delta_6 EX_{t-1} + \delta_7 TO_{t-1} \\ & + \delta_8 ER_{t-1} + \mu_{1t} \end{aligned} \quad (2)$$

D. Long-Run Estimation Model

The ARDL Long-Run Estimation Model is an econometric method used to determine long-term relationship between variables. An equation is formulated to determine the long-run coefficients, with the lag length (AIC) method.

$$\begin{aligned} FC_t = & \phi_0 + \sum_{j=1}^{p1} \phi_{1j} FC_{t-j} + \sum_{j=0}^{p2} \phi_{2j} EX_{t-j} \\ & + \sum_{j=0}^{p3} \phi_{3j} TO_{t-j} + \sum_{j=0}^{p4} \phi_{4j} ER_{t-j} + \varepsilon_t \end{aligned} \quad (3)$$

E. Short-Run Estimation Model

To examine the short-run model and its stability, the Error Correction Model (ECM) is employed, which optimizes results and analyzes variable shocks in the short term. Incorporating ECM allows for capturing deviations from long-term equilibrium and determining the reversion speed to equilibrium. The subsequent formula, developed for assessing short-run dynamics, is given below:

$$\begin{aligned} \Delta FC_t = & \varphi_0 + \sum_{j=1}^{p1} \varphi_{1j} \Delta FC_{t-j} + \sum_{j=0}^{p2} \varphi_{2j} \Delta EX_{t-j} \\ & + \sum_{j=0}^{p3} \varphi_{3j} \Delta TO_{t-j} + \sum_{j=0}^{p4} \varphi_{4j} \Delta ER_{t-j} \\ & + \lambda ECM_{t-1} + \mu_t \end{aligned} \quad (4)$$

III. ANALYSIS & DISCUSSION

The study first conducts unit root tests using both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to examine the stationarity of the variables (see [Table 1](#)). It subsequently employs the Bounds Test to ascertain the presence of a long-run co-integration relationship among the variables (see [Table 2](#)). Furthermore, the nexus between long-run and short-run relationships are determined by using the ARDL framework (see [Table 2](#)).

Here, all the time series data have to be stationary after one differentiation to perform the ARDL model in analysis. As shown in the table above, variables are integrated with $I(0)$ and $I(1)$, all of which are stationary in the first difference. However, no variable is significant at $I(2)$. For this, we can proceed with the ARDL approach. This research emphasizes the diverse interrelations between trade development and fossil fuel consumption across South Asia. In Bangladesh, a decrease in trade openness correlates with an increase in fossil fuel consumption, possibly signaling a shift towards energy-efficient or cleaner practices. However, in Nepal, a rise in trade openness is linked with an increase in fossil fuel consumption, suggesting higher energy needs for trade development fulfilled by fossil fuels. No such correlation is found in India or Pakistan. Furthermore, exports in Bangladesh and Pakistan intensify fossil fuel usage, indicating that fossil fuels power their export industries. However, Exchange Rate, although not a direct measure of trade development, significantly influences the cost and feasibility of trade and hence, fossil fuel consumption. Finally, it is established that the increasing focus on fossil fuels such as coal, oil, and natural gas continues to play a significant role in trade development in most countries (Chen et al., 2021). These variances across the region underscore the intricate dynamics between trade development and energy consumption as shaped by national policies, energy infrastructure and economic systems.

IV. CONCLUSION AND POLICY IMPLICATIONS

This paper considers the link between fossil fuel consumption and trade and business environment development on the theory/belief that using and importing more fossil fuels in developing countries could have an advan-

Table 1. Results of Unit Root Test (ADF and PP Test)

Model with constant term [Level Form]			Model with constant and trend terms [Level Form]		
Variables	ADF (<i>p</i> -value)	PP (<i>p</i> -value)	Variables	ADF (<i>p</i> -value)	PP (<i>p</i> -value)
B_FC	0.035**	0.002***	B_FC	0.155	0.285
B_EX	0.628	0.609	B_EX	0.989	0.984
B_TO	0.670	0.646	B_TO	0.338	0.871
B_ER	0.731	0.410	B_ER	0.359	0.391
I_FC	0.006***	0.000***	I_FC	0.364	0.012**
I_EX	0.751	0.745	I_EX	0.920	0.854
I_TO	0.762	0.736	I_TO	0.951	0.882
I_ER	0.977	0.968	I_ER	0.805	0.600
N_FC	0.480	0.081*	N_FC	0.105	0.207
N_EX	0.805	0.721	N_EX	0.905	0.872
N_TO	0.380	0.380	N_TO	0.832	0.832
N_ER	0.976	0.967	N_ER	0.805	0.605
P_FC	0.342	0.332	P_FC	0.920	0.939
P_EX	0.692	0.676	P_EX	0.761	0.777
P_TO	0.295	0.301	P_TO	0.309	0.296
P_ER	1.000	1.000	P_ER	0.994	0.999

Model with constant term [Difference Form]			Model with constant and trend terms [Difference Form]		
Variables	ADF (<i>p</i> -value)	PP (<i>p</i> -value)	Variables	ADF (<i>p</i> -value)	PP (<i>p</i> -value)
ΔB_FC	0.000***	0.000***	ΔB_FC	0.000***	0.000***
ΔB_EX	0.000***	0.000***	ΔB_EX	0.000***	0.000***
ΔB_TO	0.042**	0.000***	ΔB_TO	0.070*	0.000***
ΔB_ER	0.000***	0.000***	ΔB_ER	0.000***	0.000***
ΔI_FC	0.000***	0.000***	ΔI_FC	0.000***	0.000***
ΔI_EX	0.000***	0.000***	ΔI_EX	0.000***	0.000***
ΔI_TO	0.000***	0.000***	ΔI_TO	0.000***	0.000***
ΔI_ER	0.000***	0.000***	ΔI_ER	0.000***	0.000***
ΔN_FC	0.000***	0.000***	ΔN_FC	0.000***	0.000***
ΔN_EX	0.000***	0.000***	ΔN_EX	0.000***	0.000***
ΔN_TO	0.000***	0.000***	ΔN_TO	0.000***	0.001***
ΔN_ER	0.000***	0.000***	ΔN_ER	0.001***	0.000***
ΔP_FC	0.000***	0.000***	ΔP_FC	0.000***	0.000***
ΔP_EX	0.000***	0.000***	ΔP_EX	0.000***	0.000***
ΔP_TO	0.000***	0.000***	ΔP_TO	0.000***	0.000***
ΔP_ER	0.003***	0.031**	ΔP_ER	0.001***	0.031**

This table represents the results of unit root tests from the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. First, the indicators *FC*, *EX*, *TO*, and *ER* denote unit root tests at the level forms in constant terms and constant and trend terms. Second, Indicators are denoted at different forms in constant terms and constant and trend terms. Notes: *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

tageous impact on the trade environment development of a country. The ARDL framework is used to determine the long and short-run impact analysis of the selected variables from the time frame 1980 through 2020. It is identified that this relationship is far from uniform across the examined nations, highlighting the unique economic, infrastructural, and policy environments of each country. While trade openness shows a negative correlation with fossil fuel consumption in Bangladesh, a contrasting positive relationship is observed in Nepal. For India and Pakistan, no significant

relationship is identified. The study also finds that export activities in Bangladesh and Pakistan are associated with increased fossil fuel consumption. These findings underscore the criticality of adopting country-specific strategies in addressing fossil fuel consumption while also taking into account trade development trajectories.

From the above findings, this paper emphasizes the necessity of developing policies which take into account the impact of fossil fuel consumption on trade environment development in South Asia. As the region continues to ex-

Table 2. ARDL Bounds Test with Long and Short Run Analysis:

	Bangladesh		India		Nepal		Pakistan	
Lag	(1,0,1,0)		(2,0,0,0)		(2,0,0,2)		(1,1,1,1)	
Functional Format	B_FC = (B_FC / B_EX, B_TO, B_ER)		I_FC = (I_FC / I_EX, I_TO, I_ER)		N_FC = (N_FC / N_EX, N_TO, N_ER)		P_FC = (P_FC / P_EX, P_TO, P_ER)	
F-Stat.	6.514***		5.706***		6.394***		4.585***	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
10%	2.37	3.2	2.37	3.2	2.37	3.2	2.37	3.2
5%	2.79	3.67	2.79	3.67	2.79	3.67	2.79	3.67
1%	3.65	4.66	3.65	4.66	3.65	4.66	3.65	4.66
Long-run Estimation Results								
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
EX	3.285	0.00***	-2.499	0.51	0.013	0.95	4.111	0.00***
TO	-1.437	0.00***	0.826	0.60	0.216	0.06*	-1.039	0.12
ER	0.104	0.06*	0.228	0.04**	-0.059	0.01**	0.082	0.22
C	92.35	0.00***	83.29	0.00***	-4.484	0.01**	32.23	0.10
Short-run Estimation Results								
ΔEX	1.885	0.00***	-0.460	0.47	0.011	0.96	-0.740	0.02**
ΔTO	-0.648	0.00***	0.152	0.57	0.183	0.05**	0.057	0.71
ΔER	0.059	0.10*	0.042	0.08*	0.053	0.35	0.203	0.00***
ECM(-1)	-0.573	0.00***	-0.184	0.00***	-0.847	0.00***	-0.235	0.00***
Diagnostic Results								
	Chi2- Value	p-value	Chi2 Value	p-value	Chi2 Value	p-value	Chi2 Value	p-value
BG-LM	0.198	0.65	3.381	0.13	0.340	0.55	1.747	0.18
ARCH	0.593	0.44	0.229	0.62	2.592	0.27	0.184	0.66
JB Stat.	3.892	0.14	0.560	0.75	2.231	0.32	1.286	0.52
RESET	1.152	0.28	0.531	0.47	2.581	0.16	0.467	0.49
R2	0.476		0.413		0.517		0.487	
Adj R2	0.463		0.397		0.475		0.444	

This table represents the ARDL bounds test through (F. Statistics) results and also analyzes the long and short-run impact influencing the dependent variable FC. Notes: *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

perience rapid economic growth and increasing energy demands, addressing the impact of increasing fossil fuel consumption in relation to export growth, trade openness, and exchange rate stability is critical for the long-term prosperity and growth of the region. Future research could further delve into the different socio-economic factors con-

tributing to these varying relationships to contribute to more informed and sustainable policymaking.

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