Modelling Asymmetric effect of Foreign direct investment inflows (FDI), Carbon emission (CO_2) and Economic growth(EG) on energy consumption(CE) of South Asian region: A Symmetrical and Asymmetrical Panel Autoregressive Distributive Lag Model Approach (Non-linear PARDL)

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Abstract:
This study employs both linear panel autoregressive distributive lag model (Linear PARDL) and Non-linear panel autoregressive distributive lag model (Nonlinear-PARDL) by utilizing panel data from 1971 to 2014.This study also employs asymmetric granger casualty test in order to examine asymmetrical bidirectional casualty between energy consumption, carbon emission, foreign direct investment inflows and economic growth of Pakistan, India, Nepal, Sri-Lanka, and Bangladesh. Main purpose of utilizing both linear and nonlinear model is to investigate that either impact of carbon emission, economic growth and foreign direct investment on energy consumption is linear or non-linear. Cross sectional dependence test and cross sectional augmented IPS panel unit root test are also employed in order to find out cross sectional dependence and stationarity of variables respectively. Symmetrical ARDL model fails to establish long-term co-integration between variables. However, NARDL model reports asymmetrical co-integration between foreign direct investment, energy consumption, economic growth, carbon emission in long run. Asymmetrical granger casualty results report bidirectional asymmetric granger casualty between positive and negative shocks to energy consumption and economic growth.

Keywords: energy consumption and carbon emission, Panel Non-linear ARDL model, Panel linear ARDL model, asymmetric granger casualty test

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1. Introduction:

South Asia's energy market is rapidly expanding. The total demand has risen by 80% since 2000, with the access of millions of new customers (Harishankar, 2015; K. Munir & Riaz, 2019; Rahman & Velayutham, 2020). The pressure on energy systems is being

exerted, and CO2 emissions are also rising due to the duplication of the fossil fuel consumption. For sustainable growth and development, reduction in poverty, understanding about energy-growth nexus is important (Asad, Iftikhar, & Jafary, 2019). One of the factors for the value of energy is its function in industrialization, environmental development and sustainability, access to schooling and improved access to drinking water. In order to provide an integrated solution for reducing greenhouse gas emissions, renewable power infrastructure has become widely recognized as an essential component. Renewable power infrastructure is critical for creativity, economic growth to be fostered, access to safe, and renewable and inexpensive electricity production.

Most of South Asian economies are searching of sporadic replacement for non-renewable sources of energy such as Oil and Coal. Urbanization and economic expansion have increased energy demand. The journey for economic growth is crucially guided by energy resources and financial stability in South Asian countries. In most South Asian nations, more than 50 percent of total energy production is supplied from a single source, namely India (Coal 67.9%), Nepal (Hydro-Power 99.9%), Bangladesh (Natural Gas 91.5%) and Sri Lanka (Oil–50.2%). The hydroelectricity potential of Nepal alone is massive i.e. 83,000 MW. The Nepal energy trading business is attractive and will also boost energy security in South Asian countries. With regards to Asian context, where most stratagems are designed to stimulate economic progress, it seems necessary to improve energy usage. Some of the main questions addressed in empirical studies is whether increased energy usage is reliably responsible for more economic growth or whether energy conservation in some conditions is more efficient.

Linearity has been widely discussed in energy consumption-economic growth literature. There are several key findings in the analysis of a linear relation between the two variables (Asad & Qadeer, 2014). The first is that, in absolute terms, the effect of a depreciation or an appreciation in one variable on the other is the same. Secondly, in a linear framework, it is assumed that macroeconomic events, internals and externals, or changes in economic policy, do not impact the model (Pandey & Vipul, 2018; Andriansyah & Messinis, 2019; Olaleke, 2019; Salvatore, 2019). But such techniques can be complicated because they do not accurately represent real characteristics of the relationship. Empirical research shown that macroeconomic ties are not necessarily linear (Bagchi, 2017; Constantinos, 2019). Our research article is intended to explore asymmetrical effect of regressors on energy utilization by considering panel data from selected South Asian economies.

In the literature on energy economics, numerous studies have demonstrated the occurrence of nonlinearities in the association between the EC[1] and EG[2] by estimating time series econometric approaches (Usama, 2014; Muhammad, 2017; Baz et al., 2019; Luqman, Ahmad, & Bakhsh, 2019).The analysis of asymmetries across EC and EG underscores economic facts. Specific asymmetric parameters can be calculated. Asymmetric relationships are formed if positive shock to independent variables

[1] EC = “ENERGY CONSUMPTION”
[2] EG= “ECONOMIC GROWTH”

influence the dependent variable differently from negative shocks (Kouton, 2019; Sheikh, Mukhtar, Asad, & Ahmed, 2020). An appreciation in energy consumption is given the name of energy utilization and negative shock to energy consumption is linked with energy conservation strategies (Kouton, 2019). This is momentous heterogeneity as conservation of energy and energy utilization might not have the equivalent effect on EG. Nevertheless, an energy conservation policy is not effective in a circumstance in which declining energy consumption limits economic development. Even if a reduction in consumption of energy is without impact on economic development, energy conservancy are acceptable (Kouton, 2019). Time series approaches are sometimes not desirable over Panel data techniques inferable from their inability to address issues related to the weak power of the outmoded stationarity testing approaches and the cointegration test (Kouton, 2019). This study differs in following different ways from existing studies.

Firstly, in existing literature several researchers have found co-integrating links between the energy usage and economic development of various South Asian countries including Malaysia (Chor, 2009), China(Tehreem, 2018), Pakistan (Abdul, 2019b), India (Rajesh, 2019) and Bangladesh (Rani, 2019) by utilizing time series data. These research papers have used symmetric models to study the effects of economic growth on energy usage, without considering multivariate asymmetrical Panel models. Nonetheless, several research articles also investigate symmetrical impact of energy utilization on economic development by using panel models like Panel ARDL (Jeelanie, 2019), Granger Causality test for panel data (Usama, 2014, 2015; Pradhan, Arvin, & Ghoshray, 2015; Andriansyah & Messinis, 2019; Badry, 2019; Harishankar, 2015; Jeelanie, 2019). However, such studies are limited to different context like South African region (Usama, 2014), oil producing countries of Sub-Saharan region (Usama, 2014), MENA region (Badry, 2019), and other advanced, emerging and developing countries (Usama, 2015; G., 2020).

Our research article explores the asymmetric and symmetric relationship by using panel data for five (5) South Asian economies and departs from mainstream articles on economic development and utilization of energy. Secondly, in existing literature, all studies have been country-specific to date and linear relations are mostly taken into consideration when panel data are used. However, few studies used nonlinear autoregressive distributive lag models (NARDL) in existing literature. Most of them are responsible for investigating asymmetrical linkages between EC and EG by means of country specific time series econometric approaches (A. Muhammad, 2017b, 2017a; Rajesh, 2019; Salvatore, 2019; Baz et al., 2019).

Third, some research articles have found symmetrical association amongst EC and EG by using time series data (Shahbaz, Lahiani, Abosedra, & Hammoudeh, 2018; Abdul, 2019a, 2019b; Ali, 2019; Hamit, 2019; Rani, 2019). Some of research articles departed from mainstream and examined symmetrical relationship between EC and EG by utilizing Panel data modelling (Usama, 2014; Pradhan et al., 2015; Khalil, Asad, & Khan, 2018; Yue, Lu, Shen, & Chen, 2019; Andriansyah & Messinis, 2019; Badry, 2019; Jeelanie, 2019; Kouton, 2019; Çağrı, 2019; G., 2020; Liddle & Sadorsky, 2020). They

were interested in examining symmetrical long run equilibrium association between EC and EG in different context than South Asian region like MENA (Badry, 2019), South Africa (G., 2020), G7 countries (Jeelanie, 2019), BRICS (Çağrı, 2019; Yilanci et al., 2019) and other Sub-Saharan (Usama, 2014). Most common observation from literature review of existing research articles is about inconsideration of any control variable in energy consumption-growth interconnection.

Fourth, this study employs both panel NARDL model and Panel ARDL model in order to explore symmetrical and asymmetrical influence of FDI inflows, carbon emission and economic development on energy consumption of south Asian region.

PMG estimates restrict long-term coefficients to the same, while short-term coefficients can differ across countries. Awodumi and Adewuyi, (2020) mentioned that the association of EC and EG is assumed to be long-term and affected by systemic parameters. The estimation of the long term relationship alone is expected to lead to spurious results (Kouton, 2019). Therefore, it is consequential to examine the whole complexity of the subtleties between EC and GDP. The pecuniary justification supporting the estimation of the Pooled Mean group estimates is that the connection between EC and EG varies across economies and for shorter horizons. Similar behavior with regard to energy usage and economic development is also probable over longer term. One explanation is that Asian organizations like the Asian Development Bank or other multilateral entities have introduced strategies regarding access to energy with the goal of achieving adequate and equitable energy. Furthermore, they also aim to increase the output of energy. Consequently, if the desired goals are met, the implementation of these common policies could have a hard-wearing effect on the Asian economy.

In this research, results from symmetrical panel ARDL model indicated that economic growth, carbon emission and foreign direct investment inflows in selected countries of south Asian region cannot influence energy consumption in long run. However, nonlinear panel ARDL model established asymmetrical co-integration between variables in long run. Wald test statistics for asymmetries explains that EG is having an asymmetric effect on energy utilization for shorter and longer horizons because positive fluctuations of EG are not affecting the energy consumption in same ways as negative shocks to EG are affecting.

Moreover, there also exist long term asymmetrical relationship between EC and foreign direct investment inflows. 1% appreciation in positive shocks to foreign direct investment inflows appreciates EC both in long run and short run by 49% and 71%. For longer horizons, EC also appreciates with appreciation in positive shocks associated with carbon emission. 1% appreciation in positive shocks to carbon emission also increases energy consumption by 41% for longer horizons and 89% for shorter horizons. In our research articles, as discussed earlier, oil consumption per kg is used as proxy for energy consumption. Interestingly, increase and decrease in positive shocks (negative shocks) to carbon emission are having direct (inverse) effect on energy consumption.

The rest of paper consists of 4 different sections. In Section 2, authors explain about theoretical perspectives that underpins relationship between EC and EG. Same section also deals with symmetrical and asymmetrical relationship between EC, EG, CE[3] and FDI[4] inflows. Third section is about the information regarding dependent and independent variables. Fourth and fifth section deals with econometric approaches and results respectively. 5th section explains conclusion briefly.

2. Literature Review:

Literature review is comprised of three main segments. The first segment discusses theoretical connotation and the scientific perspective of the partnership between utilization of energy and economic development. Linear (symmetric) and non-liner (asymmetrical) co-integration across EC, FDI inflows, EG and CE is widely discussed in section 2. The third part further discusses the influence of FDI, economic development and carbon emissions on energy consumption of south Asian region.

2.1. Energy consumption (EC) and economic growth (EG):

The association between EC and EG is elucidated by “growth hypothesis, “conservation hypothesis”, “neutral hypothesis” and “feedback hypothesis”. The hypothesis of growth suggests that EC is related unidirectional to EG. Its prognostications explain a positive effect on EG from the use of energy. Feedback theories are backed by a two-way causal interaction amongst EC and EG. This suggests the two variables are equally compatible. The principle of conservation suggests a one-directional transition from EG to EC. This may be labeled as "unidirectional causality" or the "principle of survival”. Therefore, decisions to decrease energy consumption will have only minimal implications for economic dynamics. “Neutrality hypothesis” shows that there are no underlying linkages between EC and EG.

2.2. Association between energy consumption (EC) and economic growth (EG) with particular focus on multivariate panel data models*:*

Harishankar (2015) studied the symmetrical linkages between economic development and energy utilization covering timespan from 1971 to 2010. Granger Causality Analysis and Pedroni co-integration followed by unrestricted ECM has been utilized to explore short-term and long term association between EG and energy utilization of India, Nepal, Pakistan, Bangladesh, Sri-Lanka. Jeelanie (2019) examined that either sustainable economic development is affected by renewable or non-renewable energy usage by G7 countries. The cointgeration between EC, EG, and CE were examined by using Pooled Mean Group ARDL model. Findings have demonstrated that excessive usage of fossil fuels raise carbon dioxide emissions, lead to climate change, global warming, decrease crop production and risks to life for humans.

Usama (2015) utilized panel autoregressive distributive lag model (PARDL) during times 1980-2010 and found long-term co-integration between sectoral development and EC. Themba (2020) explored linkages amongst EC and EG for the short and longer horizons. Authors have employed ARDL with bound testing approach in order to explore

[3] CE = “Carbon emissions”
[4] FDI = “Foreign direct investment inflows”

growth-energy consumption nexus in multiple different classified economies according to their status of economic progress and development. In majority of the sample countries, electricity consumption serves as contributing factor for economic growth and economic development. Waqas (2013) was interested to study the causation between EC and real income of Pakistan for period ranging from 1975-2009. Similarly, Usama (2014) investigated long-term relationship between gross domestic product and renewable and non-renewable EC in regionally classified 82 developing countries.. Furthermore, results have shown that the causation between non-renewable EC and the EG is stronger than that of renewable energy. Çağrı (2019) examined EG and EC co-integrating relationship in context of BRICS countries and utilized fixed modified ordinary least square and Pedroni co-integration techniques.

Badry (2019) was interested in probing the partnership between renewable EC and EG over the years from 2000 to 2014. The pedroni test for cointegration and restricted VAR is used for measuring long-term interplay between EC and EG. Moreover, granger casualty results have shown that causation is bidirectional. Therefore, in non-oil MENA countries, green energy should be preferred as an alternative to conventional energy to guarantee sustainable economic development without carbon emissions and to minimize reliance on foreign diesel.

The increase in natural gas, energy and effective labor utilization is a major factor in economic development (Sahbi, 2019). Long-term relation between EC and EG is analyzed using an expanded Cobb – Douglas output function and ARDL model by (Sahbi, 2019). Results showed that natural gas usage, output, resources and employment contribute to economic development. Abdul (2019) maintained their focus on the symmetrical relationship between electrical energy utilization , population growth and EG of Pakistan. Research findings show long-term linkages between the variable. Furthermore, the results show that access to electricity for urban people and population growth in the urban areas have an imperative impact on economic growth, whereas access to electricity by rural people and population expansion in rural areas have an adverse effect on economic development in Pakistan. In another article, author also illuminated the role of EC in affecting EG and found cointegration between said variables. Moreover, use of electricity is primarily associated with economic growth in agricultural, commercial and industrial sectors, while the use of residential and street light didn’t have any significant connection to economic growth (Abdul, 2019a). The findings showed that the development of thermal, hydro electrical, renewable, nuclear and oil energy is largely related to economic growth in Pakistan. Similar to Chor (2009), Abdul (2019b) has also reported the co-integration of income, electricity consumption, international investments and population in Malaysia using Granger causality and ARDL model with bound testing approach. Secondly, in Malaysia, Granger causality test indicated that electricity utilization, international investments and income are granger causing economic growth.

Masoud (2015) explored complex relationship between environmental pollution, EC and EG in Tanzania. The energy utilization (ENGY) is measured as kilowatt hour (kWh) of electricity utilization per household while environmental pollution is metric ton of carbon

emissions and per capita increase in gross domestic product (LGDP) is representation of economic development. In Tanzania, there is unidirectional causality from (LGDP) to (LENGY). Ironically, the effect of electricity utilization(LENGY) and carbon emission (LCO2) shocks over time have led to substantial economic growth (Masoud,2015). The variance decomposition indicated that the rate of variability to carbon emissions from shocks to economic growth (LGDP) and energy consumption (LENGY) amounted to 46% and 41% respectively.

Hamit (2019) has used the Toda-Yamamoto approach and Autogressive distributed Lag (ARDL) model to evaluate the cointegration between renewable energies and economic development of Bulgaria for the duration 1990 to 2016. Findings revealed that renewable energy utilization for enhancing production within economy is source of economic growth. The long term equilibrium association between agricultural EG and EC in Pakistan by employing time series data from 1984-2016 is also examined in an empirical manner by (Chandio & Ali, 2019). Results of the ARDL model demonstrated cointegration between the study variables. The findings of their study have shown that agricultural economic development is positively affected both by long-term and short-term gas and electricity consumption. Ume (2019) investigated whether there are any links between energy consumption and industrial, agricultural production and Nigerian economy's growth pace. Authors made use of annualized statistics from the World Bank indicators for economic development from 1971 to 2014, and employed autoregressive distributed lag methods for data analysis as well as bound testing approach and error correction model for shorter and longer horizons.

The ties between EC and EG metrics have been very strong in China (Tehreem, 2018), Bangladesh (Rani, 2019), India (Salman, 2019) Pakistan (Chandio & Ali, 2019). Rani (2019) examined Bangladesh's causal relation between the usage of electricity per capita and the gross national income per capita (GNI) for the period 1971–2014 and only found short term relationship between both. The complex ties of industrial energy utilization, industrial value added (Shaker, Asad, & Zulfiqar, 2018), financial development (FD) and trade openness is examined in Indian context by (Salman, 2019). Salman (2019) included the annual frequency data for the duration 1971–2016 for both aggregates and disaggregated variables. The ARDL is used to estimate the long run association between variables and furthermore the effects of co-integration are verified by Johansen and Juselius (1990) and the vector correction method. It is also observed that the research supported the energy conventional approaches encouraging the implementation of energy conservation policies in the industrial sector. To reach an increased energy quality standard, the energy management program needs to be carefully planned. This leads to sustainable productivity and low carbon emissions.

Tehreem (2018) utilized VECM and granger causality test in order to examine relationship between aggregated and disaggregated commercial energy consumption, carbon emissions, and industrial production in China. In the industrial sector, the author concluded that the aggregated and disaggregated energy consumption raises CO2 emissions. The VECM Granger causality results showed the bidirectional causation

between CO2 emission and industrial growth as well as aggregate and disaggregate energy consumption (coal, petroleum and natural gas) (Tehreem, 2018).

2.3. Association between energy consumption (EC) and economic growth (EG) with particular emphasis on asymmetrical models:

Luqman et al. (2019) investigated long-term asymmetrical co-integration between EG and EC covering period from Q1 1960 to Q3 2018. In fact, positive and negative shocks to renewable energy and nuclear energy have a profound effect on economic development. Another paper explores the asymmetric connection between EC and EG by incorporating financial development, capital and employment in the Indian economy's production mechanism between 1960Q1 and 2015Q4 (Shahbaz et al., 2017). In their study, NARDL model is used and the causal association between the variables is also examined by an asymmetric Granger causality test. The results showed that the variables are asymmetrically cointegrated. Asymmetric Granger casualty findings suggested that only negative energy consumption shocks are granger causing economic growth. Fuinhas and Marques (2012) examined the effect on the Portuguese economy by using quarterly data on energy usage and capital development. A significant energy consumption shock is estimated to have a positive economic growth impact. Shahbaz, Lahiani, Abosedra, and Hammoudeh (2018) have examined the cointegration between globalization and energy usage by utilizing the newly established Quantile Autoregressive Distributed Lag model. The model is estimated by using quarterly data between 1970Q1 and 2015Q4 from two of the most globalized nations, the Netherlands and Ireland. The studies have also shown a strong association between globalization, financial development of both countries and long-term energy usage.

In the existing literature on the asymmetrical ties between EC , agriculture, capital, and EG in Pakistan, (Baz et al., 2019) used (NARDL) model by taking into account time series data between 1971 and 2014. NARDL findings displayed asymmetrical co-integration of the variables. Charfeddine and Barkat (2020) investigated asymmetrical impact of oil and gas prices shocks on the overall real gross domestic product. In their research article, two econometric methods were employed: Structural vector autoregressive model (AB-SVARX) and nonlinear autoregressive distributed lag model (NARDL). The findings demonstrated that both real GDP and non-oil real GDP react, in the short term, to adverse oil price fluctuations and oil and gas revenues. But the results indicated that the shock’s effect is no longer than three quarters. The NARDL results further showed that positive oil price variations have a greater impact on economic activity than negative fluctuations for longer horizons. This has demonstrated the Qatar economy's resistance to adverse shocks and the energy sector's role in growing Qatar's degree of economic diversification. Hamilton (2003) is one of the pioneering works about energy-growth nexus. Author has highlighted the importance of using non-linear oil price change specifications for the Gross Domestic product (GDP). Omay et al. (2014) have shown a non-linear correlation between the consumption of energy and EG in G7 countries from 1977 to 2007, utilizing non-linear panel cointegration and causality tests.

For Turkey, Nazlioglu, Kayhan, and Adiguzel (2014) and Araç and Hasanov (2014) examined nonlinearities regarding energy usage and economic growth. In study of Nazlioglu et al. (2014) authors have considered the period from 1967 to 2007 and nonlinear Granger causality tests together with Bound testing co-integration approach has been implemented. Both authors have found Long-term associationship between EC and EG. However, from 1960 to 2010, Araç and Hasanov (2014) have used smooth transition VAR model. The asymmetric relation between EC and EG in the Turkish economy has been found by employing Smooth Transition Vector Autoregressive model and results showed that economic growth is more influenced by negative energy shocks than positive energy shocks. Araç and Hasanov (2014) explored causal links between the use of electricity and economic growth in Turkey during the period 1967–2007. Moreover, for purpose of achieving the said objective, Authors have utilized three methodological approaches for econometric time series: Co-integration with bound testing approach, the Granger linear causality test; and the Granger nonlinear causality test. The nonlinear Granger causality results are more scientifically accurate and robust for Turkey than the Granger linear causality analysis The study of non-linear causality supports the hypothesis of neutrality, which indicates that energy conservation strategy didn't affect Turkish EG.

2.4 Relationship between carbon emission (CE), Foreign direct investment (FDI), Economic growth (EG) and energy consumption (EC):

In existing studies, researchers accentuate on co-intgeratinng relationship between environmental degradation, EG and FDI using panel cointegration for the 1980-2007 period (Pao & Tsai, 2011). CO2 emissions appears to be elastic in long-term equilibrium and are FDI inelastic, and the results substantiate the hypothesis for the Environmental Curve Kuznets (EKC). The causality results showed that there is high bidirectional causality between carbon emissions and FDI, and strong unidirectional causality between output and FDI (Asad, 2010). In fact, there is also clear two-way causation between EG and EC, while a powerful one-way causality from EC to CE is also demonstrated. Ting, Yin, and Ying (2011) decomposed level of energy consumption into the FDI scale impact, FDI structure and the FDI technology effect by using the logarithmic mean divisia index model. The results showed that the impact of FDI scale reduces the ferocity of energy consumption. The structural and technical influence of FDI does not necessarily foster a reduction in the rate of energy consumption (Asad, Iftikhar, & Jafary, 2019). In another study, the foreign direct investment influence on energy utilization for Shandong province was proved to be poor, with a negative FDI scaling effect and FDI systemic effect and a positive FDI technical effect (Wang & Jiayu, 2019).

Association amongst FDI and CE for the regions of the Middle East and North Africa (MENA) is examined covering timespan from 1990-2015 by (Shahbaz et al., 2019). The N-shaped association of FDI and carbon emissions is also validated by using Generalized methods of moments(GMM) model. Inverted U and N-shaped casual links between economic growth and carbon emissions confirmed Environmental Kuznets Curve (EKC) hypothesis. Causality results revealed that Biomass energy consumption reduces emissions of carbon, and FDI causes CO2 emission. The results clearly

confirm presence of feedback effect between EG and CE. The relationship between urbanization, EC, FDI and CE of 17 South and Southeastern Asian (SSEA) countries were evaluated during the 1980-2012 period by (Liobikienė & Butkus, 2019). The results of the Pedroni co-integrations demonstrated that in any subgroup of a country, energy consumption, FDI and CO2 emissions are co-integrated.

Wasti and Zaidi (2020) used an auto-regressive distributional lag model to determine the influence of EC, EG , FDI and financial development on CE of Kuwait covering period from 1980 to 2013. The findings of long-term co-integration between variables have been confirmed. Munir, Lean, and Smyth (2020) found that income and energy utilization have considerable influence on CO2 emissions, while FDI is of little pertinence. In Indonesia and Thailand, there exists two-way causation between EG and CE, while in Malaysia, authors reported unidirectional casualties from GDP to CO2. Bidirectional causality exists between FDI and CO2 emission and energy consumption by transport industry of Thailand and Malaysia. The underlying goal of the another study is to add value to the attributes that optimize Asian economic development. Muhammad and Khan (2019) applied generalized moments method (GMM) and random effect model using panel data from Asian countries covering period from 2001 to 2012. Findings highlighted that energy consumption, FDI inflows and FDI exports, CO2 emissions, and capital are determinates of economic growth in Asian countries.

Sun, Tan, and Yang (2020) explored the impact of FDI on EC. FDI is a financing source which facilitates companies to expand and is also having significant impact on economic growth and prosperity. Zhu, Duan, Guo, and Yu (2016) explored the effect of FDI, EG, and EC on carbon emissions of selected Member States of the (ASEAN) by using panel quantile regression model.

3.0 Data

Panel dataset obtained from the data base of world bank containing country specific information regarding foreign direct investment inflows, EC, CE and economic growth (GDP per capita). The data is concurrently collected over the largest amount of time and also for the maximum number of economies (Pakistan, India, Nepal, Sri Lanka and Bangladesh). Dataset used in this analysis has been configured according to the following procedures. For 5 out of 8 South Asian countries, the WDI database offers full data on energy consumption (kg of oil equivalent per capita), Foreign direct investment (Foreign direct investment net inflows), Carbon emission (CO2 intensity Kg per Kg of oil equivalent), economic growth (GDP per capita) from 1970 to 2014. Variables are extensively used in the South-Asian literature on integration between EC, CE, FDI and EG (Muhammad & Khan, 2019). Datasets for variables of energy consumption, FDI inflows and carbon emission for 5 of the 8 countries from 1971 to 2014 were fully accessible at this point. Therefore, from 1971 to 2014 our Panel is comprised of 5 South Asian countries. The Panel dataset provides adequate information for appropriate research (220 observations). The final countries listed are: Pakistan, India, Sri-Lanka, Nepal and Bangladesh. Following is brief description of dependent and independent variables incorporated in our study.

Table 1: Description of Independent and Dependent Variables

Dependent variable	Independent variable	Incorporated in previous studies
Energy consumption(EC)	Economic growth(EG)	(Rahman & Velayutham, 2020)
Energy consumption(EC)	Foreign direct investment (FDI)	(Paramati et al., 2016)
Energy consumption(EC)	Carbon emission(CE)	(Khan, Peng, & Li,2019; Muhammad, 2019)

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Table 1 shows some examples from existing research articles which have employed energy consumption as dependent and carbon emission, foreign direct investment and economic growth as independent variable.

4.0 Research Methodology

The key purpose of this research paper is the analysis of the asymmetrical impact of economic development, foreign direct investments and CO_2 emissions on energy usage. Both asymmetrical and symmetrical panel ARDL and NARDL models are utilized to investigate that either the impact of underlying variables on EC is actually linear or non-linear. The econometric methodology portion is focused on three main parts. The first part is the study of the stochastic properties and data heterogeneity.

4.1 Panel Unit root testing for seasonality and heterogeneity analysis:

Cross sectional augmented unit root test CIPS is applicable in presence of cross sectional dependence in Panel data set. However, Panel unit root test like (LLU) and (Fisher-ADF) are conducted for panel data without cross sectional dependence in order to confirm that none of variables became stationary at second differencing for application of panel ARDL and NARDL. Schwarz information criteria(SIC) is used for optimal lag length and CIPS results are reported in **table 3**.

CIPS statistics is given by CIPS(N,T) = $N^{-1}\sum_{i=1}^{N} t_i\ (N,T)$,

The presence or absence of cross-sectional dependency is tested through the Cross-sectional Dependence Test (CD Test) of Paseran (2004).

CD = $\sqrt{\frac{2T}{N(N-1)}}\ (\sum_{i=1}^{N-1}\sum_{j=1+1}^{N}\hat{\rho_{i,j}})$,

N= Number of countries, T= time period, $\hat{\rho_{i,j}}$ = pairwise correlation of residuals. CD test results are reported in **table 2**.

4.2 Panel ARDL and Panel NARDL models with bound testing approach:

Both panel ARDL and Panel NARDL models are utilized for investigating linear and asymmetrical impact of EG in presence of CE and FDI inflows on EC. Comparison of both panel based ARDL and NARDL models is necessary to examine that either relationship between EG and EC is symmetrical or non-linear. In first instance, panel based ARDL and NARDL models are computed to find out symmetrical and asymmetrical effect of EG, carbon emissions and foreign direct investment inflows on EC. Results from both models can be seen in **table no 4**.

General form of panel error correction model for linear Panel ARDL model is given below,

$$\Delta EC_{it} = \alpha_{0i} + \pi_{1i}\xi_{it-1} + \sum_{j=1}^{p}\gamma_{ij}\,\Delta \mathrm{EC}_{it-j} + \sum_{j=0}^{q}\delta_{ij}\,\Delta x_{it-j} + u_i + \epsilon_{it} \quad \text{.....1a}$$

$\mathrm{EC(energy\ consumption)\ represents\ dependent\ varaibles\ in\ equation\ 1a.}$ ξ_{it-1} is about long run equilibrium in symmetrical panel ARDL model. π is coefficient that measures speed of adjustment. x indicates list of possible independent variables like economic growth along with other control variables like carbon emission, foreign direct investment inflows. p and q are lag orders of regressand and regressors respectively.

Panel ARDL model specification adopted by this study is given below.

$$\Delta EC_{it} = \alpha_{0i} + \alpha_{1i}y_{it-1} + \beta_{1j}x_{it-1} + \sum_{j=1}^{p}\gamma_{ij}\,\Delta EC_{it-j} + \sum_{j=0}^{q}\delta_{ij}x_{it-j} + u_i + \varepsilon_{it} \quad \text{.....2a}$$

EC represents dependent variable (energy consumption) in equation 2a, p and q are lag order of dependent and independent variables. Δ indicates that variables are converted into stationary form after first differencing. α and β are short run coefficient of dependent and independent variables respectively. Long run coefficients are denoted by γ and δ respectivey. However main purpose of this research article is to estimate asymmetrical effect of EC on EG in presence of certain control variables like carbon emission and foreign direct investment inflows. All independent variables are represented by x. Asymmetrical ARDL modelling technique by Shin et al. (2014) is having the capability to disintegrate regressors and regressand into positive and negative signs. Therefore, EG, FDI, CE can be disintegrated into their respective positive and negative shocks in following manner,

$$x_{it}^{+} = \sum_{k=1}^{t}\Delta x_{ik}^{+} = \sum_{k=1}^{t}\max(\Delta x_{ik,}0) \quad \text{.....3}$$

$$x_{it}^{-} = \sum_{k=1}^{t}\Delta x_{ik}^{-} = \sum_{k=1}^{t}\min(\Delta x_{ik,}0) \quad \text{.....4}$$

EC is disintegrated into positive and negative shocks in following manner,

$y_{it}^{+} = \sum_{k=1}^{t} \Delta y_{ik}^{+} = \sum_{k=1}^{t} \max(\Delta y_{ik,} 0)$.....5

$y_{it}^{-} = \sum_{k=1}^{t} \Delta y_{ik}^{-} = \sum_{k=1}^{t} \min(\Delta y_{ik,} 0)$.....6

The representation of Panel NARDL is given below,

$\Delta EC_{it} = \alpha_0 + \alpha_1 EC_{it-1} + \alpha_2^{+} x_{it-1}^{+} + \alpha_2^{-} x_{it-1}^{-} + \sum_{k=1}^{p} \beta_k \Delta EC_{it-k} + \sum_{k=0}^{q} (\delta_k^{+} \Delta x_{it-k}^{+} + \delta_k^{-} \Delta x_{it-k}^{-}) + u_i + \varepsilon_{it}$.....7

In equation no 7, energy consumption is taken as dependent variables and economic growth as independent variable. This serves to find out the asymmetric effect of EG on EC in presence of control variables like foreign direct investment inflows and carbon emissions. $\alpha_2^{+} x_{it-1}^{+}$and $\alpha_2^{-} x_{it-1}^{-}$ represents that regressors are decomposed into +ve and -ve shocks for investigating long run non-linear impact on dependent variable. δ_k^{+} and δ_k^{-} captures short run asymmetry. NARDL model by Shin et al. (2014) is an extension of ARDL model by Pesaran et al. (2001). Wald test statistics is used to find out short run and long run non-linear effect. If values of $-{}^{\alpha_2^{+}}/_{\alpha_1} = -{}^{\alpha_2^{-}}/_{\alpha_1}$ then there exist no long run asymmetric effect. If value of δ_k^{+} is not equal to δ_k^{-} then there exist short run asymmetrical effect. Asymmetric error correction model is represented below,

$\Delta EC_{it} = \alpha_{0i} + \pi_{1i}^{+} \xi_{it-1}^{+} + \pi_{1i}^{-} \xi_{it-1}^{-} + \sum_{j=1}^{p} \gamma_{ij}^{+} \Delta EC_{it-j}^{+} + \sum_{j=1}^{p} \gamma_{ij}^{-} \Delta EC_{it-j}^{-} + \sum_{j=1}^{p} \delta_{ij}^{+} \Delta x_{it-j}^{+} + \sum_{j=1}^{p} \delta_{ij}^{-} \Delta x_{it-j}^{-} + u_i + \varepsilon_{it}$.....8

Equation 8 represents asymmetrical error correction model. ξ_{it-1} Captures long run equilibrium in asymmetrical Panel ARDL model. The coefficient π is the speed of adjustment which estimates the time required by the system to get back long-run equilibrium. According to equation 9a and 9b, ΔEC is dependent variables in differences i.e. first differences of energy consumption

4.3 Asymmetrical Granger causality analysis:

The findings of the asymmetric Granger causality analysis are stated in table 5 after estimating the short and long run asymmetric impact of EG on EC in presence of certain control variables like foreign direct investment inflows and carbon emission.

5.0 Results:

Table 2 reports outcomes of descriptive statistics of regressors and dependent variable incorporated in our study. A variance of coefficient can be used to quantify heterogeneity within panel data sets. In comparison to energy consumption and carbon emission, the variance of coefficient is high for economic growth and foreign direct investment in the south Asian region. This indicates the heterogeneity within corresponding panel data sets representing economic growth and carbon emission for 5 out of 8 countries of south Asian region. Multiple factors of each country, such as the different economic plans, political stability, research and development initiatives may

lead to the increase in coefficient of variation of economic development and Foreign direct investment inflows. While descriptive analysis performed in this section revealed the heterogeneity of our results, it is important to confirm this with Cross sectional dependence test. This is commonly known as Pesaran CD test.

Table2: Descriptive statistics

Variables	Mean	Min	Max	Std.Dev	Skewness	Kurtosis	Coef. of Variation	observation
Economic growth (GDP)	2.61	-15.38	9.0039	2.90	-1.59	9.69	1.08	220
Energy consumption (Kg of oil equivalent)	323.47	86.76	636.57	118.48	-0.18	2.75	0.36	220
Carbon Emission (co2)	1.23	0.054	2.71	0.67	-0.01	2.20	0.54	220
Foreign direct investment inflows (FDI)	0.55	-0.098	3.66	0.70	1.81	6.97	1.27	220

Table 2 is representation of description for whole panel of selected south Asian countries including India, Nepal, Bangladesh, Sri Lanka, Pakistan

Table 2 and 3 reports the findings of heterogeneity in panel data set and the Panel unit root tests respectively. We proceed by estimating the cross-sectional dependence in all underlying variables. Table 2 summarizes the results. For all variables, the null hypothesis for cross sectional independence is rejected. The p-values of the Statistic are less than the 1% and 5% significance threshold. The findings therefore indicate that all underlying variables are cross sectional dependent across the countries. These results are compatible with finding of other research articles (Kouton, 2019; Munir et al., 2020). Kouton (2019) aimed to illustrate asymmetrical heterogeneous relationships between EC and EG of 19 African nations between 1971 and 2014. Authors have utilized a non-linear autoregressive distributive lag model for heterogeneous panel data and asymmetric causality test after estimating Pesaran's CD test and Cross sectional augmented IPS panel unit root test. CD test statistics identified presence of cross sectional dependence and CIPS panel unit root test furthermore identified the presence of heterogeneity and non-stationarity in variables at level. The empirical findings

demonstrate the asymmetries between EC and EG of selected countries of Africa (Kouton, 2019).

Table 2: Pesaran's (2004) cross sectional dependence unit root test results:

Variables	CD Test	P value
Economic growth	10.43***	0.0054
Energy consumption	8.65***	0.01
Carbon emissions	9.29***	0.0098
FDI Inflows	3.12***	0.00013

The evidence for the existence of cross-sectoral dependency in the energy utilization and actual GDP can be explained in following ways. Cross-sectional dependence in all underlying variables may emerge from spillover effects between countries at the local or regional level. A supply shock, for example in countries which export energy, can likely affect countries that import energy. Furthermore, the existence of cross sectional dependency in energy utilization could be clarified by global specific convulsions with heterogeneous consequences across countries such as the oil crisis in the 1970s or global financial crisis in 2008. Furthermore, more broadly, with respect to actual GDP per capita as most of economies today's world are related to each other and shocks impacting one economy could also impact other economies as a consequence of globalized businesses and international convergence between selected south Asian economies.

Cross sectional dependence in foreign direct investment inflows may be due to the heterogeneous infrastructure development index, financial development, business easiness, technological advancements, interest rate, stock market development, political and financial stability across countries in our Panel. Those countries with more financial resources, political stability and developed infrastructure will draw more influxes of foreign direct investment relative to political and financial unstable countries. However, conventional and first generation panel unit root test (like LLC, Hadri and F-ADF) cannot be able to draw robust results in presence of cross sectional dependence (Q. Munir et al., 2020). Cross sectional augmented IPS unit root test is applied in order to find out that none of variable became stationary at second differencing.

Table3: Cross sectional augmented IPS unit root testing:

Variables	CIPS 1	CIPS 2	CIPS 3	Critical value(5%)	CIPS 1	CIPS 2	CIPS 3	Critical value	Order of variables
	At level				At first differencing				
Energy consumption	-1.51	-1.75	-1.87	-2.50	-3.69	-3.98	-4.01	-3.46	I(1)
Economic	-1.75	-1.98	-2.20	-3.65	-2.75	-2.85	-2.65	-4.12	I(1)

growth(GDP)									
Carbon emission(CO 2)	-2.29	-3.398	-3.76	-4.76	-2.08	-2.16	-2.76	-3.65	I(1)
FDI inflows	-1.99	-2.23	-3.87	-4.88	-3.69	-3.76	-3.87	-5.12	I(1)

Note: Null hypotheses and Cross sectional augmented panel unit root test is rejected if CIPS test statistics is greater than critical values.

Cross sectional augmented IPS unit root test for panel data is more appropriate for variables exhibiting cross sectional dependence properties. After identification of cross sectional dependence in all underlying variables, panel unit root test purposed by Pesaran in 2007 is more appropriate in order to identify seasonality effects in variables. Accordingly, we conduct the Pesaran's 2007 CIPS unit root test on the basis of CD test results. As mentioned earlier, the test will also give us information about the potential heterogeneity of the series in addition to checking of the seasonality effects under assumption of cross sectional dependence. Three separate lags are used to carry out the test. Table 3 reports that none of variables became stationary at second differencing. Results also reported that all variables are having unit root at level and became stationary after first differencing. This furthermore confirmed that Panel ARDL and Panel NARDL models are appropriate for this study.

After identification of cross sectional dependence test and application of Pesaran's cross sectional augmented IPS unit root test for panel data, Panel based nonlinear and linear Autoregressive distributive lag models are applied in order to investigate symmetrical and asymmetrical effect of economic growth, carbon emission and foreign direct investment inflows on EC. Panel linear and nonlinear ARDL models are applied in order to investigate that either the relationship between underlying variables is symmetrical or asymmetrical in nature.

Hausman test is also conducted separately for symmetrical and asymmetrical models in order to identify that either appropriate method for both models is mean group estimation or Pooled mean group estimation. Hausman test results indicated that both symmetrical and asymmetrical should be estimated using pooled mean group estimators. Results for Hausman test are provided table at end of table no 4. Table no 4 is divided into two section. First section reports results for linear ARDL for panel data representing 5 out of 8 south Asian economies. Second section is comprising of panel based Nonlinear autoregressive distributive lag model. Each independent variable is decomposed into positive and negative shocks according to procedure listed in equation 3 and 4. Symmetrical and Asymmetrical error correction model is also computed in order to find out long run integration between underlying variables. Both models are compared on basis of Error correction model, wald tests and corresponding values of coefficients along with their significant probability values.

Econometric procedure of applying Non-linear ARDL model after identification of cross sectional dependence and cross section Augmented IPS unit root test is in line with(Kouton, 2019). Residual diagnostics include the application of various test for cross sectional dependence including Breusch pegan LM test, Pesaran's 2004 Cross sectional dependence test known as CD test and Pesaran's LM scaled test. Separate results are provided in table 5. Asymmetric granger casualty results are reported in table 6.

Table 4: Symmetrical Panel ARDL and Asymmetrical Panel ARDL models

Variables	Panel ARDL			Panel NARDL(PMG)		
	Coefficient	Std.error	P-value	coefficient	Std.error	P.values
Dependent Variable: Energy consumption (Kg of oil equivalent)						
Long run coefficient:						
lnEG	0.26	0.45	0.55			
InFDI	0.180	0.39	0.985			
InCO2	0.253	0.41	0.34			
InEG+				+0.114**	0.145	0.023
EG-				+0.16**	0.113	0.01
InFDI+				+0.49***	0.11	0.001
FDI-				-0.13	0.139	0.79
InCO2+				0.41**	0.191	0.013
C02 -				+0.19***	0.121	0.000021
Short run coefficient						
lnEG	0.639*	0.26	0.0914			
InFDI	0.216	0.19	0.299			
InCO2	0.49*	0.115	0.098			
InEG+				0.463**	0.31	0.01
EG-				0.91	0.17	0.215
lnFDI +				0.71***	0.197	0.0001
FDI -				0.31	0.533	0.257
InCO2+				0.89*	0.316	0.067

C02-				-0.187	0.59	0.19
ECT(-1)	0.65(0.99)			-0.71***		
Wald test for short run and long run joint significant in case of Panel ARDL						
Wald test for short run Joint significance	1.29(0.045)					
Wald test for long run Joint significance	1.71(0.11)					
Wald test for short run and long run Asymmetries						
$lnEG_{SR}$				2.15**		
$lnCo2_{LR}$				1.98**		
$lnFDI_{SR}$				1.81**		
$lnFDI_{LR}$				1.154*		
$lnCO2_{SR}$				2.92*		
$lnCO2_{LR}$				1.45**		
Hausman test	1.71			1.22(0.45)		

Table 4 reports that symmetrical panel based ARDL model cannot be able to establish a long term association between economic growth, foreign direct investment inflows, carbon emission and energy consumption. Moreover, symmetrical ECT is also non-negative and insignificant. ECT is the rate of change which shows that how speedily variables are adjusted towards long term equilibrium and its negative sign reflects short-term convergence (Abdul, 2019a, 2019b; A. Muhammad, 2017). In panel ARDL model, Wald test is utilized for finding out short run and long run joint significant of independent variables in affecting energy consumption. Results from symmetrical panel ARDL model indicated that economic growth, carbon emission and foreign direct investment inflows in selected countries of south Asian region cannot influence EC in long term. But, in short run, only economic growth and carbon emissions are influencing energy consumption at 10% significant level. Result of Panel ARDL model shows that 1% appreciation in economic growth and carbon emission are causing 63.9% and 49% appreciation in EC in short run. These findings are in line with (Khan, Peng, & Li, 2019) who have utilised generalised methods of moments and found an impact of carbon emmisson on energy consumption. Wald test of Panel ARDL model indicates that all variables are jointly influencing energy consumption in short run at 10% significant level.

However long term symmetrical relationship between energy consumption and underlying variables cannot be established by Panel ARDL model.

We also utilize Panel based non-linear ARDL model and established asymmetrical long run relationship between EC and EG, CE and FDI inflows. In 2nd section of Table 4, results of Panel NARDL are given. Positive and negative shock to EG is influencing EC in positive and negative way respectively. Positive and negative shocks associated with economic growth are causing 11.4% appreciation in energy consumption and 16% depreciation in energy consumption in long run. This means that magnitude of negative shocks associated with economic growth is more aggressively influencing energy consumption as compared to positive shocks related to EG in long term. However, for shorter horizons, only positive shocks to economic growth are causing a significant influence on EC e.g. 1% appreciation in positive shocks to GDP per capita will increase energy consumption by 46.3%. Wald test statistics for short and long term asymmetries explains that EG is having an asymmetric effect on EC both for short term and longer horizons because positive fluctuations in energy growth is not affecting the energy consumption in same ways as negative shocks to economic growth are affecting[5].

As discussed earlier, depreciation in energy consumption is linked with energy reduction strategies aimed at national level of each country. Such energy conservation policies are only effective if they are having positive or neutral effect on national economies.

Long run asymmetrical association between EC and EG is inconsistent with other researches such as (Ali, 2019; Awodumi & Adewuyi, 2020; Çağrı, 2019; Chor, 2009; Jeelanie, 2019; Luqman et al., 2019; Razmi et al., 2020; Sahbi, 2019; Shahbaz et al., 2018; Ume, 2019; Usama, 2014; Zhu et al., 2016) because these studies didn't incorporate both symmetrical and asymmetrical panel based nonlinear autoregressive distributive lag models and assumed only symmetrical long term association between EC and EG. Furthermore, these researches have taken economic growth as dependent variable. However, few research articles studied the impact of EG on EC and found significant long run relationship between both variables(Muhammad, 2019; Al-mulali, Fereidouni, Lee, & Sab, 2013; Chontanawat, 2020; Kahouli, 2019). Our study adds to existing literature by concluding long run asymmetrical impact of EG on EC. Long run asymmetrical association between EC and EG is mainly due to contribution of economic growth in enhancing the utilization of kg of oil per capita which may also lead towards environmental degradation.
Table 4 reports that there exist long term non-linear association between EC and FDI inflows. However, for shorter and longer horizons, only positive shocks to foreign direct

[5] Asymmetrical association between regrressors and refressand can be established if there exist positive or direct relationship between positive shocks to economic growth and indirect, negative or inverse relationship is established between negative shocks to economic growth and energy consumption. However, asymmetrical relationship is also established on the basis of magnitude of coefficient values, For example, according to table no 4, positive shocks to economic growth causes 11.4% increase in energy consumption but negative shocks to economic growth causes 16% decrease in energy consumption. This means that magnitude of negative shocks to economic growth is more adversely impacting energy consumption as compared to positive shocks to economic growth(see Muhammad, 2017a). Wald test statistics are used to detect non-linearity between variables.

investment inflows are affecting energy consumption. 1% appreciation in positive shocks to foreign direct investment inflows appreciates EC both in long run and short run by 49% and 71%. This means that magnitude of positive shocks to foreign direct investment are having greater impact on EC in short run as compared to long run. Wald test statistics explains that impact of positive shocks to FDI inflows on energy consumption is not equal to impact of negative shocks to FDI inflows. Long run co-integrating association between FDI inflows and EC is consistent with (Abdullah, 2013; Muhammad & Khan, 2019; Pao & Tsai, 2011; Ting et al., 2011; Wang & Jiayu, 2019; Zhu et al., 2016). However, these studies have only found symmetrical relationship between energy consumption and economic growth and didn't consider asymmetries between both underlying variables. In our study, Panel based symmetrical ARDL model fails to establish long term relationship between FDI inflows and EC for shorter and longer horizons.

In long run, EC also increases with appreciation in positive shocks associated with carbon emission. 1% appreciation in positive shocks to carbon emission also increases energy consumption by 41% in long run and 89% in short run. In our research articles, as discussed earlier, oil consumption per kg is used as proxy for energy consumption. Interestingly, increase and decrease in positive shocks (negative shocks) to carbon emission are having direct (inverse) effect on energy consumption. In case of a negative shock to carbon emission, energy consumption decreases by 19%. This means that oil consumption in South Asian region is mainly reason for economic growth as well as environmental degradation. Oil consumption not only depends upon positive inflows of foreign direct investment but also major cause of economic development along with environmental degradation in South Asian region. Table 4 explains that there exists a non-linear asymmetrical relationship between CE and EC and Symmetrical Panel ARDL model fails to establish a long run association between carbon emission and EC. Table 5 reports that nonlinear panel ARDL model is cross sectional dependent. Null hypothesis of breusch pagan LM test, Pesaran Scaled LM test and Pesaran CD test of cross sectional independence is rejected at 1% significance threshold.

Table 5: Diagnostic testing:

Model Panel NARDL	Test	Statistics (p value)	Results
Model Panel NARDL	Breusch Pagan LM Test	0.61***(0.0076)	cross sectional dependence
Model Panel NARDL	Pesaran Scaled LM test	0.35***(0.0021)	cross sectional dependence
Model Panel NARDL	Pesaran CD test	0.49***(0.0012)	cross sectional dependence

Table 6 reports the result of asymmetric granger casualty from positive and negative partial sum of EC towards EG, partial positive and negative sums of EG to EC, partial and negative sums of EC towards partial positive and negative sums of FDI, partial

positive and negative sums of FDI inflows towards partial and negative sums of energy consumption , partial and negative sums of energy consumption towards carbon emission and partial positive and negative sums of carbon emission towards partial and negative sums of energy consumption, partial and negative sums of FDI inflows towards partial and negative sums of economic growth and particle and negative sums of economic growth towards partial and negative sums of FDI inflows.

Table 6: Asymmetric Granger Casualty analysis:

Model	F-statistics	Causality
$EC^{+} \rightarrow EG^{+}$	1.24**	Yes
$EC^{-} \rightarrow EG^{-}$	2.43***	Yes
$EC^{+} \rightarrow EG^{-}$	1.65	No
$EC^{-} \rightarrow EG^{+}$	1.22	No
$EG^{+} \rightarrow EC^{+}$	5.67***	Yes
$EG^{-} \rightarrow EC^{-}$	4.76**	Yes
$EG^{+} \rightarrow EC^{-}$	2.76	No
$EG^{-} \rightarrow EC^{+}$	3.98	No
$EC^{+} \rightarrow FDI^{+}$	1.75**	Yes
$EC^{-} \rightarrow FDI^{-}$	1.65	No
$EC^{+} \rightarrow FDI^{-}$	1.98	No
$EC^{-} \rightarrow FDI^{+}$	2.43	No
$FDI^{+} \rightarrow EC^{+}$	1.85	No
$FDI^{-} \rightarrow EC^{-}$	1.10	No
$FDI^{+} \rightarrow EC^{-}$	2.39	No
$FDI^{-} \rightarrow EC^{+}$	1.76	No
$EC^{+} \rightarrow CO2^{+}$	1.09**	Yes
$EC^{-} \rightarrow CO2^{-}$	1.31*	Yes
$EC^{-} \rightarrow CO2^{+}$	2.45	No
$EC^{+} \rightarrow CO2^{-}$	0.91	No

$CO2^{+} \rightarrow EC^{+}$	3.65***	Yes
$CO2^{-} \rightarrow EC^{-}$	1.199**	Yes
$CO2^{+} \rightarrow EC^{-}$	1.23	No
$CO2^{-} \rightarrow EC^{+}$	1.32	No
$FDI^{+} \rightarrow EG^{+}$	3.26**	Yes
$FDI^{-} \rightarrow EG^{-}$	2.45**	Yes
$FDI^{+} \rightarrow EG^{-}$	1.29	No
$FDI^{-} \rightarrow EG^{+}$	1.17	No
$EG^{+} \rightarrow FDI^{+}$	1.11***	Yes
$EG^{-} \rightarrow FDI^{-}$	1.187	No
$EG^{+} \rightarrow FDI^{-}$	1.14	No
$EG^{-} \rightarrow FDI^{+}$	1.10	No

Table 6 reports bidirectional asymmetric causality between partial positive and negative sums of EC and positive and negative partial sums of EG. This means that positive and negative shocks to EC are granger causing positive and negative shocks to EG and positive and negative shocks to EG are granger causing positive and negative shocks to EC respectively. Positive shocks to energy consumption may be results of energy utilization policies and negative shock to energy consumption is result of energy conservation. As discussed earlier energy conservation policies are granger causing negative shocks to economic growth. Such energy conservation policies are not much desirable which are having negative effect on region's economy. Government of respective countries should revisit their policies in such a way that energy conservation strategies lead towards better EG. Nevertheless, there is unidirectional causality from partial positive sums of energy consumption towards positive shocks to foreign direct investment inflows.

Table 6 also reports a bidirectional asymmetric casualty between negative and positive partial sums of energy utilization and partial negative and positive sums of carbon emission. Economic growth in south Asian region is dependent upon consumption of oil which also leads towards environmental degradation.

Conclusions:

Our research article departs from mainstream articles regarding economic development and energy utilization by investigating asymmetrical co-integration between energy consumption and economic growth using Panel data for South Asian markets including Pakistan, India, Sri-Lanka, Bangladesh, Nepal. We also introduced control variables like FDI inflows and Carbon emissions. Moreover, in existing literature, to date all studies have been country-specific and have shown linear relations which are mostly taken into consideration when panel data are used. However, few studies used Nonlinear autoregressive distributive lag models (NARDL) in existing literature. Most of them are responsible for investigating asymmetrical association between energy utilization and economic development using country specific time series econometric approaches. This study employs both linear (P-ARDL) and non-linear panel autoregressive distributive lag model (P-NARDL) after estimating Pesaran cross sectional dependence test (CD Test) and cross section augment IPS panel unit root test(CIPS), in order to explore association between energy utilization, FDI inflows, carbon emission and economic growth of south Asian region. This approach helps us to consider the symmetrical and asymmetrical influence of economic development, foreign direct investment inflows and carbon emission on energy consumption. Asymmetric granger casualty test is also used to investigate asymmetric unidirectional or bidirectional casualty running from underlying variables towards each other.

In long run asymmetric association exist between energy utilization, economic development, FDI inflows and carbon emission. Positive shocks associated with independent variables didn't effect energy consumption the same way as negative shocks are affecting. Interestingly only positive shocks to economic growth, FDI inflows and carbon emission are having an effect on energy consumption and negative shocks to independent variables didn't effect energy utilization in short run. Nonetheless Symmetrical panel based ARDL model unable to estimate a long-term co-integration between EC and EG.

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