

Nexus of CO₂ emissions and economic growth in Pakistan: analysis by using extended stirpat model

Syed Aziz Rasool (✉ dr.aziz@szabist-isb.edu.pk)

Shaheed Zulfikar Ali Bhutto Institute of Science and Technology - Islamabad Campus

<https://orcid.org/0000-0002-6149-1822>

Tariq Rahim

SZABIST: Shaheed Zulfikar Ali Bhutto Institute of Science and Technology

Muhammad Ali Khan

SZABIST: Shaheed Zulfikar Ali Bhutto Institute of Science and Technology

Research

Keywords: CO₂ emissions, economic growth, STIRPAT model, Greenhouse gasses, GDP per capita, Energy

Posted Date: October 5th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-882639/v1>

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Abstract

The main purpose of this study is to analyze the relationship between economic growth (GDP per capita) and CO₂ emissions in Pakistan. This study applies the theoretical framework of Dietz and Rosa's STIRPAT Model, widely used for assessing the environment quality. The additional major determinants of CO₂ emissions introduced by the extended STIRPAT model include total energy use, Industry, value-added, financial development, trade openness, and urban population. The empirical results reveal that; total energy use has a positive and significant relationship with CO₂ emissions. The relationship between GDP and CO₂ emissions is positive and insignificant in the country. Industry, value-added has an insignificant relationship with CO₂ emissions in the country. The urban population has a direct and positive relationship with CO₂ emissions. Trade openness has a long-run positive and significant relationship with CO₂ emissions in the country. In general, this case study offers a relevant policy for controlling the enhancement in the CO₂ emissions in the selected sample unit; Pakistan, and other similar states that possess the same socio-economic condition.

1. Introduction

1.1. BACKGROUND

The environmental issues are getting important over time as more anthropogenic activities eventually result in more emissions. The melting of glaciers, the rising water levels in the oceans, and the rise of air temperature are clear indicators of global warming and climate change. The United Nations [1] has designed 17 sustainable development goals to address the contemporary challenges of the world. Goal 13 is as "Take urgent action to combat climate change and its impacts." Since climate change is one of the acute problems/challenges faced by the contemporary world, its causation and impacts should be the priority of practitioners related to environmental economics and climate change. South Asia is the worst hit by climate change in the past two decades, revealed by Germanwatch [2] in its 2020 Climate Risk Index annual report. Given that, Pakistan is the 5th most affected country in the 21st century from 2000 to 2019.

Greenhouse gasses deposition in the atmosphere is considered the major reason for climate change and global warming. According to US Environmental Protection Agency [3], CO₂ emissions comprise 76% of the total house gas emissions. Therefore, to mitigate its impacts on climate change, the determinants of CO₂ emission should be rightly identified.

A rapid increase has been observed in CO₂ emission with the enhancement of economic activities worldwide. The GDP per capita (current US\$) of Pakistan has increased from 576.1956 to 1368.454 between 2000 and 2016. Similarly, the CO₂ emissions (metric tons per capita) of Pakistan have increased from 0.747834 to 0.987832 between 2000 and 2016 [4]. Moreover, the enhancement in industrialization and economic activities increased energy consumption, which results in the rise of carbon dioxide (CO₂) emissions in the country. Carbon pathways.

Based on the findings of the Germanwatch Climate Risk Index annual report 2020, the focus area of this inquiry is Pakistan. For this purpose, this study analyzed the nexus of economic growth and CO₂ emissions within the theoretical framework of the STIRPAT model in the country. Moreover, the additional anthropogenic activities that cause CO₂ emissions are incorporated by the extended STIRPAT model, includes energy use, urban population, financial development, and trade openness.

1.2. PROBLEM STATEMENT

Enhancement of CO₂ emissions is one of the alarming issues of the contemporary world because it is one of the major root causes of climate change and global warming. To combat climate change and its impacts controlling CO₂ emissions should be first taken into consideration. Numbers of efforts had made worldwide to mitigate CO₂ emissions, the focus area of this study is Pakistan. The rationale for choosing this sample unit is based on the Climate Risk Index annual report published by Germanwatch in 2020 [2]. According to Climate Risk Index 2020, Pakistan is the fifth most affected country in the 21st century. The mitigation of CO₂ emissions is only possible through the identification and control of its determinates. For this purpose, this study is an attempt to analyze the nexus of economic growth and CO₂ emissions within the theoretical framework of the Ditz and Rosa STIRPAT model in the selected sample unit Pakistan.

1.3. RESEARCH OBJECTIVES

1. The objective of the research is to inquire about the association of CO₂ emissions with the gross domestic product (GDP) and related measures in Pakistan
2. To find out whether the association is short-term or long-term between CO₂ emissions and GDP.

1.4. RESEARCH QUESTIONS

Q1. Why there is an association between CO₂ emissions and GDP per capita in Pakistan?

Q2. What type (long or short run) of a relationship exists between CO₂ emissions and GDP per capita in the country?

1.5. SIGNIFICANCE OF THE STUDY

Climate change and global warming are the two immense problems of the present world and one of the major reasons for its happening is CO₂ emissions. This research study analyzed the connection between CO₂ emissions (dependent variable) and GDP. Based on the available literature, it is found that this research topic is very little explored in the context of Pakistan, so this research study is very useful in this regard. The findings of this study are very useful to the students and researchers who are going to conduct research

studies in this particular area of climate change, global warming, CO₂ emissions, and its possible determinants. Moreover, this study enriches the available literature on this specific topic of analyzing the connection between CO₂ emission and GDP, and other major contributors of CO₂ emissions. It is also very useful for the governments and policymakers while formulating the climate change and environmental policies in Pakistan.

1.6. CONTRIBUTION OF THE PAPER

The current research work devotes to the existent body of literature on the determinants of CO₂ by bringing up the STRIPAT model in the context of Pakistan in its first attempt as far the knowledge of researches, to analyze the interaction between CO₂ emissions and GDP, with the inclusion of other major explanatory variables: Urban population, financial development, total energy consumption and trade openness. This study updates the previous work by inducting different variables, collectively into a single extended STRIPAT model. Moreover, introducing the dynamic time series econometric estimation models; the Autoregressive Distributed Lag Model in the presence of the structural breaks and the Error Correction Model within ARDL methodology, enhance the quality of the empirical findings. This study also ensures the robustness of results by incorporating the advanced cointegration technique: Hatime-J cointegration tests, into the analysis.

1.7. ORGANIZATION OF THE PAPER

The rest of the paper is organized in this order. The first portion of the paper is consisting of an introduction, problem statement, research objectives, research questions, and research significance. The second portion of the paper is consisting of a literature review and literature gap. The third portion is consisting of theoretical framework, data analysis techniques, type of study, unit of analysis, time horizon, and econometric estimation models. The fourth portion of this study is consisting of empirical results interpretation and analysis in the context of Pakistan. The fifth chapter is consisting of a conclusion and relevant policy recommendations for Pakistan, The bibliography and the supporting materials to the study are attached in the appendix.

2. Literature Review

The association between CO₂ emissions and its driving forces is studied both in developed and developing countries. During these studies, several econometric models are being used to analyze the interaction between CO₂ emissions and their impact factors. As Ghosh and coworkers used the VAR model [5], Begum and coworkers used the ARDL bounds testing approach [6], Hammami and Saidi [7] used the Generalized Method of Moments model and Ghazali and Ali [8] used extended STRIPAT model. This particular study is based on an extended STRPAT model so the literature reviewed in this section will be mostly using the STRIPAT model to analyze the relationships between CO₂ emissions and its driving forces.

Ghazali and Ali. [8] analyzed the impact of different carbon emissions drivers in the new technological advanced countries for the years between 1991 and 2013 by employing an extended STIRPAT model. To study the relationship between CO₂ emissions and economic growth, technology, population, and extensive factors energy mix, energy intensity, the productivity of labor, employment level of urban population and trade openness by using the regression (group means dynamic commonly correlated estimator). To check the robustness of the results of group mean a dynamic common correlated estimator is compared with ordinary least square techniques. According to the findings of the study carbon emissions intensity, energy intensity, gross domestic products, and population are the main causing agents of CO₂ emissions.

Xue et al. [9] studied the connection between energy intensity, GDP, population and urbanization with the CO₂ emissions in the Yangtze River Delta, China. The time for this study was 1990 to 2011. This study was based on the STIRPAT model. To predict different scenarios of CO₂ emissions between the years, 2015 to 2020 vector machine model was made. According to the findings, CO₂ emissions had increased for both the time from 1990 to 2011 and 2015 to 2020. Moreover, energy intensity finds to be the main influencing force of CO₂ emissions while the population is the lesser driving force of CO₂ emissions. But the influencing position of energy intensity had decreased over time in the long term. The paper suggests that the association between urban population and CO₂ emissions considered being U-shaped. The gross domestic product had more influence on CO₂ emissions than urbanization and population.

Ahmad et al. [10] studied the interaction between the sector of construction, consumption of energy, gross regional product, urban population, and carbon dioxide emissions by employing the STIRPAT model. Augmented mean group and dynamic mean group are used to estimate the panel of china and the other three disaggregated regional panels. According to the findings of the study, the association between carbon dioxide emissions, the construction sector, energy consumption, gross regional product, and urbanization was found to be long-run equilibrium.

Yang et al. [11] stated that the growing trend of CO₂ emissions varied across the years from 1995 to 2014 in Zhejiang, China. This study employed an extended STIRPAT model for its conduction. The results of the study showed that the urbanization level and gross domestic product were the major driving forces of the CO₂ emissions from 1996 to 1999 in Zhejiang, China. While economic development and foreign trade were the major contributors to CO₂ emissions from 2000 to 2014.

It is noticed in the review of the literature that different studies used different determinants of CO₂ emissions. The maximum number of studies that applied the STIRPAT model is carried in developed countries, and very little focus is given to developing regions. Studies conducted to analyze the impact of Economic growth on CO₂ emission in the context of Pakistan ignored the combined effects of other main determinants/ Explanatory variables of CO₂ emissions. Moreover, the structural breaks in the series due to geopolitical and economic changes are overlooked during estimations. In addition, the results of the review studies are not consistent with each other, and vary from country to country and study to study. To fulfill these gaps in the literature, this study is conducted on a selected sample unit; Pakistan.

3. Methodology

3.1. THEORETICAL FRAMEWORK

Dietz and Rosa's Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model [12] is used to conduct this study. STIRPAT model is not the very first attempt to study the environmental impact through socioeconomic variables. The STIRPAT model is derived from Ehrlich and Holdren's (1971) IPAT model [13]. However the IPAT model was reformulated from Duncan's (1959) POET model.

3.2. STIRPAT

According to Dietz and Rosa [12], all the influencing factors included in the IPAT model effects the deviations in the CO₂ emissions. IPAT model was reformulated into a stochastic model by Dietz and Rosa due to the criticism on the very base of the IPAT equation. The criticism of the IPAT model is described in the next paragraph.

Comprehensive criticism had been made on the IPAT model. According to Scholz [14], the IPAT model only inducts demographic and economic forces into the IPAT equation while ignoring the other factors/forces. Moreover, studying the relationship between the variables the concept of proportionality is taken into consideration, which is imposed by the basic principle for accounting equations. York et al. [15] stated that implying if the population being triple then the environmental impact would be triple when all the other factors in the equation remain constant. Moreover, the IPAT equation being constant cannot be extended to other scenarios and situations. This character of the IPAT equation is limiting the applicability of the IPAT model in the case of social science theories which require modification and extended hypothesis testing. The theoretical model employed for this study is known as "Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) "to check the impact of economic growth, financial development, trade openness, energy consumption, and urbanization on CO₂ emissions.

STIRPAT Model is the modified form of environmental stress equation: $I=P \times A \times T$

Where "I" represent environmental impact, "P" represents the population, "A" represents affluence and "T" represents technology.

Dietz and Rosa [12] presented the STIRPAT model to explain the driving forces that are impacting the environment. STIRPAT model simultaneously combines economic, societal, and technological factors to resolve the environmental problems. Here in this study in equation (1), I is the environmental issues that are represented by carbon dioxide emissions, P is the societal parameter that is represented by the urban population. A is the economy parameter that is represented by gross domestic product. T is the technological parameter that is represented by the utilization of renewable energy.

Econometric equation is

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln neu_{it} + \beta_2 \ln fd_{it} + \beta_3 \ln gdp_{it} + \beta_4 \ln Indust_{it} + \beta_5 \ln to_{it} + \beta_6 \ln up_{it} + \mu_{it}$$

(3)

Where: $i = 1, 2, \dots, 4$, $t = 1, 2, 3, \dots, 42$

$\ln CO_2$; Shows the natural log of CO₂ emissions (metric tons per capita)

$\ln eu$; Shows the natural log of energy use (kg of oil equivalent per capita)

$\ln fd$; Shows the natural log of FD¹ (% of GDP)

$\ln gdp$; Shows the natural log of GDP per capita (current US\$)

$\ln Indust$; Shows the natural log of Industry, value added (current US\$)

$\ln to$; Shows the natural log of trade openness² (% of GDP)

$\ln up$; Shows the natural log of urban population (% of the total population)

Moreover, according to Dietz and Rosa [12], STIRPAT is an interdisciplinary model that combines the social sciences with the ecological sciences. Because of this character hypothesis in the field of social sciences that are linked with ecological sciences can be tested through this model. Thus variables from the other fields such as economics, political and cultural sciences can be inducted into the STIRPAT model equation.

3.3. Time horizon

This study covers 42 years of data from 1975 to 2016. The period of the study is based on the updated data provided by World Bank till November 1st, 2020.

3.4. Elementary data analysis

Data collection is followed by elementary data analysis. Elementary data analysis in this study includes; a brief description of descriptive statics and the formulation of the PairWise simple correlation coefficient matrix.

3.5. Econometric analysis

The econometric analysis of this study includes:

1) Unit root tests 2) Model selection 3) Cointegration tests 4) Dynamic econometric models for the estimations of the long-run and the short-run coefficients. 5) Post estimation diagnostic tests.

3.6. Unit root tests

Checking the stationarity of data is the first step to do econometric analysis through dynamic econometric models. For this purpose, conventional unit root tests such as Augmented Dickey-Fuller (ADF) unit root test by Dickey and Fuller [16], Phillips and Perron [17] unit root test is applied. The findings of the Phillips Perron unit root test are considered superior to those of the ADF unit root test as it eliminates the limitations of serial correlation and heteroscedasticity, proven in Augmented Dickey-Fuller. However, it is observed that the conventional unit root tests may present biased and misleading results in the presence of structural breaks in the data Shahbaz et al. [18]. To overcome the shortcoming of the Augmented Dickey-Fuller unit and Phillips-Perron (PP) unit root test, Zivot and Andrews [19] unit root test is also incorporated accompanied.

3.7. Criteria for Model selection

The robust estimation of econometric data can be obtained through the application of dynamic econometric models. The selection of the econometric model is based on the order of integration of data. Figure-2 describes the criteria for the selection of an econometric model based on the Stationarity of the data.

Based on the findings of the unit root tests, this study used the Autoregressive-Distributed Lag Model, Autoregressive-Distributed Lag Model-Error Correction model; ARDL-Bound test for cointegration, G-H and H-j cointegration tests for econometric estimation.

3.8. Autoregressive Distributed Lag Model

For the sake of estimating the long-run relationship between the dependent variable and independent variable, this study employs the ARDL-bounds co-integration approach, introduced by Pesaran et al. [20]. As the name of the ARDL indicates that ARDL is a distributed lag model that incorporates the lagged values of the dependent variable and the current and lagged values of the explanatory variables. ARDL model takes into account both the exogenous and endogenous variables. Unlike the other models, the ARDL model can be applied in heterogeneous situations: the data is purely stationary at level, at first order, or the mix of both. However, the Autoregressive lag distributed model cannot be specified at the second difference of the series.

The general Autoregressive Distributed lag model for this study is specified as;

$$\begin{aligned}
\Delta \ln CO_{2it} = & \beta_0 + \sum_{i=1}^a \beta_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^b \beta_{2i} \Delta \ln neu_{t-i} + \sum_{i=0}^c \beta_{3i} \Delta \ln f d_{t-i} + \sum_{i=0}^d \beta_{4i} \Delta \ln g d p_{t-i} \\
& + \sum_{i=0}^e \beta_{5i} \Delta \ln indust_{t-i} + \sum_{i=0}^f \beta_{6i} \Delta \ln to_{t-i} + \sum_{i=0}^g \beta_{7i} \Delta \ln up_{t-i} + Dummy_t + \delta_1 \ln CO_{2t-1} \\
& + \delta_2 \ln neu_{t-1} + \delta_3 \ln f d_{t-1} + \delta_4 \ln g d p_{t-1} + \delta_5 \ln indust_{t-1} + \delta_6 \ln to_{t-1} + \delta_7 \ln up_{t-1} + \varepsilon_t
\end{aligned}
\tag{4}$$

In equation 3 Δ symbolizes the difference term, β_0 describes the constant term, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ defines the short-run coefficients, $\delta_0, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7$ represents the long-run coefficients, ε_t describes the error term. The Dummy represents' dummy variable included due to structural breaks in the series. The optimum lag length is symbolized by a, b, c, d, e, f and g which will be obtained through Akaike information criteria in this study.

3.9. ARDL-Bounds test for Cointegration:

The ARDL-Bounds test for cointegration is used to analyze the long-run relationship between variables within ARDL Methodology.

The null hypothesis for ARDL- cointegration states there is no cointegration between variables.

(H_0 : constant term= long run coefficients=0)

The alternate hypothesis for ARDL-cointegration states there is a cointegration relationship between variables.

H_1 : constant term \neq long-run coefficients \neq 0

The decision to either validate the null hypothesis or alternate hypothesis is based on the F-statics value of the ARDL-bounds test. The F-statics is compared with the upper bound and lower bound critical values introduced by Pesaran et al.[20] and Narayan [21]. The F-statics values higher than the upper bound critical value validates the alternate hypothesis. Whereas, the F-statics value lesser than the lower bound critical value validates the null hypothesis. However, the F-statics value lies between upper and lower bound values neither validate the null hypothesis nor the alternate hypothesis, and the decision remains inconclusive.

3.10. ARDL-ECM

Once the cointegration relationship is confirmed between the variables through the ARDL-Bounds test, and long-run coefficients are estimated, the short-run coefficients are estimated through ARDL-ECM estimations.

Then general ARDL-ECM for this study is specified as:

$$\begin{aligned} \Delta \ln CO_{2it} = & \gamma_0 + \sum_{i=1}^m \gamma_{1i} \Delta \ln CO_{2t-i} + \sum_{i=0}^n \gamma_{2i} \Delta \ln neu_{t-i} + \sum_{i=0}^o \gamma_{3i} \Delta \ln fd_{t-i} + \sum_{i=0}^p \gamma_{4i} \Delta \ln gdp_{t-i} \\ & + \sum_{i=0}^q \gamma_{5i} \Delta \ln indust_{t-i} + \sum_{i=0}^r \gamma_{6i} \Delta \ln to_{t-i} + \sum_{i=0}^s \gamma_{7i} \Delta \ln up_{t-i} + Dummy_t + \sigma ECT_{t-1} + \varepsilon_t \end{aligned} \quad (5)$$

In equation 4 Δ symbolizes the difference term, γ_0 define the constant term, $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6$ represent the short-run coefficients; ε_t the error term; and σ represents the coefficient of error correction term. The optimum lag length is symbolized by m, n, o, p, q, and r, which will be obtained through the Akaike information criteria in this study.

3.11. Hatemi-J Cointegration tests

To increase the robustness of the ARDL bound estimations, this study incorporates the Hatemi-j [22] cointegration tests for analyzing the long-run relationships between the variables. The Gauss formulated coding program is employed for Hatemi-J co integration's estimations.

The time-series data consisting of the macroeconomic indicators come across various shocks, put forward by the economic, financial, and technological changes, regime shifts, and other related factors. Numerous conventional cointegration techniques are used to study the relationship between the macroeconomic variables, but its estimations are not authentic due to structural breaks or shocks within the series. Hatemi-j apprehended the limitations of traditional cointegration tests through the modified techniques that analyze the cointegration relationship between the variables in the presence of regime changes or structural breaks endogenously.

Monte Carlo simulation techniques regard the validity of the estimation of Hatemi-j cointegration tests. Gregory takes the lead to analyze the cointegration relationship within variables in the existence of one structural break, and Hatemi-J advanced it to cover two unknown structural breaks.

AH-J³ cointegration test with two unknown structural breaks:

H₀: No cointegration among variables with two unknown structural breaks

Condition: ADF or Zt test statics < Asymptotic critical value at 1% or 5% or 10%)

Where ADF: Modified ADF Test statics value; Zt: Modified Phillips Test statics value.

3.12. Structural Break and Structural Dummies

The dummies incorporated in the ARDL model are based on the breaking points/structural breaks computed in the Hatemi-J cointegration techniques.

This study used the following structural breaks analysis techniques:

1. Z-Andrew unit root test with structural breaks
2. G-Hansen cointegration test with a regime shift
3. AH-J cointegration test with two unknown structural breaks.

The ZA and GH techniques compute the one unknown structural break, while the HJ defines two unknown structural breaks. HJ test is the advanced form of Zivot Andrews and Gregory Hansen cointegration techniques, and its estimations are more preferable to the prior one. Hence this study incorporated the Hatmi-J cointegration defined structural breaks in long-run and short-run econometric analysis.

Structural Dummy: Dummy Y

Values assigning criteria for Dummy is:

Observation Year \geq breaking year =1

Observation Year < breaking year=0

4. Results Interpretation And Discussion

4.1. Elementary Data Analysis

The elementary properties of the data are discussed in this chapter. Table-1 describes the descriptive properties of the data, whereas table-2 presents the correlation matrix.

Table 1 *Descriptive statics of Series*

	LnCO2	LnEU	LnFD	LnGDP	LnIndust	LnTO	LnUP
Mean	-0.436	6.005	3.113	6.232	23.27191	3.477	3.453
Median	-0.337	6.076	3.149	6.126	23.30285	3.494	3.464
Maximum	-0.012	6.215	3.394	7.221	24.66779	3.650	3.589
Minimum	-1.103	5.700	2.728	5.124	21.56379	3.231	3.271
Std. Dev.	0.332	0.159	0.170	0.557	0.864052	0.108	0.092
Skewness	-0.577	-0.649	-0.702	0.196	0.014603	-0.653	-0.305
Kurtosis	2.146	2.005	2.824	2.222	2.126546	2.673	1.954
Jarque-Bera	3.610317	4.683024	3.511972	1.330299	1.336605	3.176142	2.566770
Probability	0.164	0.096	0.172	0.514	0.512578	0.204	0.277
Observations	42	42	42	42	42	42	42

Source: Author's calculation in EViews 10

The values of Jarque-Bera and its probability are placed in the 10th and 11th rows of the table. These values measure the normality of the skewness and kurtosis. Jarque-Bera tests the null hypothesis of normal data distribution. As reported, the Jarque-Bera test statistics probability is higher than 0.05% across the table, so the null hypothesis of the normal distribution is accepted for the entire set of variables.

4.2. Unit root tests results

This study used three different unit root tests; Augmented Dickey-Fuller, Phillips Perron, and Zivot Andrews for checking the stationary of the data. The results are displayed and discussed in this section.

Augmented Dickey-Fuller (ADF) Unit Root Test

Table 2: *ADF unit root test at intercept & trend*

Augmented Dickey-Fuller test statistic (intercept & trend)				
Variables	Level	1 st difference	T-critical value at 5 % level	
				Order
LnCO2	-1.308177	-8.691284	-3.526609	I(1)
LnEU	0.166631	-6.047286	-3.526609	I(1)
LnFD	-1.924241	-5.127029	-3.526609	I(1)
LnGDP	-2.215345	-5.833550	-3.526609	I(1)
LnIndustry	-2.606591	-5.328607	-3.526609	I(1)
LnTO	-2.098701	-6.458811	-3.526609	I(1)
LnUP	-7.324758	-2.736056	-3.526609	I(0)

Source: Author's calculation in EViews 10

Table 2 reveals that the urban population is stationary at a level. It is observed that the ADF test statics values of CO2 emissions, LnEU, LnFD, LnGDP, LnIndustry and LnTO in the second column are lower than the 5% critical value, which shows these variables are non-stationary at the level. However, these variables become stationary at the first difference by fulfilling the criteria of the alternate hypothesis of no unit root.

4.3. Phillips Perron Unit Root Test

The result of the PP unit root test at intercept and intercept & trend are listed in tables 6 and

Table 3 *PP unit root test at intercept & trend*

Variables	Level	Test critical value at 5 % level		Order
		1 st difference		
LnCO2	-0.992338	-8.832456	-3.523623	I(1)
LnEU	0.166631	-6.064201	-3.523623	I(1)
LnFD	-2.170672	-5.118781	-3.523623	I(1)
LnGDP	-2.303501	-5.830968	-3.523623	I(1)
LnIndustry	-2.724279	-5.327466	-3.523623	I(1)
LnTO	-2.274971	-6.518990	-3.523623	I(1)
LnUP	-4.839048	-1.835519	-3.523623	I(0)

Source: Author's calculation in EViews 10

Table 3 presents the findings of the Phillips Perron unit root test at constant & trend. The result shows that the urban population is stationary, and the null hypothesis does not hold at the level. However, all other variables are non-stationary.

It is observed that all variables become stationary at the first difference, and the null hypothesis of unit root at constant and trend is rejected. The Phillips Perron unit root test confirmed the series Stationarity in both unit root models of intercept and intercept & trend.

4.4. Zivot Andrew Unit Root Test

The results are listed in table 4 for the Zivot-Andrews unit root test with structural breaks.

Table 4 Zivot-Andrews test statistic (intercept and trend)

Variables	Level		1 st difference				Order
	ZA T- statistics	BD	Test critical value at 5 % level	ZA T- statistics	BD	Test critical value at 5 % level	
LnCO2	-3.991841	1990	-5.08	-8.971278	2008	-5.08	I(1)
LnEU	-2.650443	1992	-5.08	-7.210799	2008	-5.08	I(1)
LnFD	-3.527908	2004	-5.08	-6.526104	2009	-5.08	I(1)
LnGDP	-4.025990	2004	-5.08	-7.058050	1983	-5.08	I(1)
LnIndustry	-4.843827	1999	-5.08	-4.680586	2004	-5.08	-
LnTO	-3.233920	1998	-4.42	-7.265699	2005	-5.08	I(1)
LnUP	-5.716962	1995	-5.08	-6.807880	1999	-5.08	I(0)

Source: Author's calculation in EViews 10

Table 4 reveals that the ZA test statics values of the urban population are higher than the 5 %test critical value at the level, which indicates the variable is stationary and possessing a breaking point in both the constant and trend. The breaking date in the intercept and trend of urban population is 1999. All the other variables are non-stationary at the level. However, after taking the first difference, all other variables become stationary with defined breaking points in both the constant and trends. The structural breaks/ breaking dates for CO₂ emissions, LnEU, LnFD, LnGDP, LnIndust, and LnTO are listed as 2008, 2008, 2009, 1983, 2004, and 2005.

Conclusion: All the Unit root tests confirm the Stationary of the data at 1st difference and almost produced consistent results. According to the findings of all three unit root tests, the order of integration for the urban population is I(0), while for all other variables is I(0).

4.5. Results of cointegration tests:

The result of the H-J cointegration tests with multiple structural breaks is listed in these sections

H-J cointegration test with two unknown structural breaks

The result of the H-J test for co-integration with two unknown structural breaks is displayed in table 5.

The variables among whom the cointegration relationship is tested include dependent variables; CO₂emissions and independent variables: total energy use, financial development, gross domestic product, trade openness, and the urban population.

Table 5

AH-J cointegration test with two unknown structural breaks in the constant and regime shift

Model-4 C/S			
		1st Breaking point	2nd Breaking point
ADF	-10.68	0.23809524	0.71428571
Zt	-11.167	0.23809524	0.71428571
ZA	-60.24	0.23809524	0.71428571
Asymptotic critical values			
	1%	5%	10%
ADF	-8.353	-7.903	-7.705
Zt	-8.353	-7.903	-7.705
ZA	-140.13	-123.87	-116.16

Source: Author's calculation in GAUSS 21

Table 5 shows that the Zt and ADF statics values are higher than 1%, 5% and 10% asymptotic critical values, which indicates the cointegration relationship among variables with two unknown structural breaks in the constant and regime shift at 1%, 5% and 10% level, Hence the null hypothesis of no cointegration is rejected in Model-4. The two breaking points computed in the Hatemi-J's cointegration test with two unknown structural breaks in the constant and regime shift are listed as 0.714 and 0.714, respectively.

Results for Cointegration Dummies:

The dummies incorporated in the ARDL model are listed in Table 6.

Table 6 Dummies used in ARDL

Breaking year	Created Dum	Values assigned	Conclusion
1985	Dummy85	Observation Year ≥ 85=1	Years 1985-2016=1
		Observation Year < 85=0	Years 1975-1984=0

Source: Author Calculation base on Hatemi-J cointegration estimation in GAUSS 21

Table 6 contains the list of dummy incorporated into the ARDL model for the estimations of long-run and short-run coefficients. This dummy is used as fixed regresses in ARDL to ensure robust econometric estimations in the presence of structural breaks in the series.

Results for Autoregressive Distributed Lag Model

The results for ARDL model are presented in tables 7, 8, and 9 respectively.

Results of ARDL-Bounds test for cointegration:

To analyze the cointegration between the dependent variable and explanatory variables, the ARDL bound test within the ARDL methodology is applied.

The variables between whom the cointegration relationship is tested include the dependent variable: CO₂ emissions, and explanatory variables: total energy use, financial development, gross domestic product, industry value-added, trade openness, and the urban population.

The results of ARDL-Bounds Cointegration test are listed in table 7.

Table 7

ARDL (1, 0, 0, 1, 1, 1, 0) Long Run Form and Bounds Test

Case 3: Unrestricted Constant and No Trend				
Test Statistic	Value	I(0)	I(1)	Signif
F-statistic	8.604835	2.12	3.23	10%
	5	2.45	3.61	5%
		2.75	3.99	2.5%
		3.15	4.43	1%

Source: Author's calculation in EViews 10

Table 7 reveals that the F-statics value (8.604835) of ARDL-Bounds is higher than its upper bound I (1) critical value (3.61) at a 5 % level, which indicates the existence of a cointegration relationship among variables of this study. Hence, the null hypothesis of no cointegration relationship among variables is rejected.

Autoregressive Distributed Lag Model long-run relationship estimations

The empirical results of the ARDL long-run relationship coefficients between dependent variable: CO₂ emissions and independent variables: energy use, financial development, gross domestic product, trade openness, and urban population are presented in table 8.

Table-8

Long Run Coefficients Estimates based on selected ARDL (1, 0, 0, 1, 1, 1, and 0).

Levels Equation				
Explanatory Variables	Coefficient	Std. Error	t-Statistic	Prob.
LnEU	0.971546	0.216491	4.487689	0.0001
LnFD	0.022646	0.044965	0.503625	0.6183
LnGDP	0.132210	0.109485	1.207567	0.2370
LnIndustry	-0.097166	0.103142	-0.942062	0.3539
LnTO	0.171177	0.071415	2.396931	0.0232
LnUP	2.364946	0.695619	3.399769	0.0020
$EC = LNCO2 - (0.9715 * LNEU + 0.0226 * LNFD + 0.1322 * LNGDP - 0.0972 * LNINDUST + 0.1712 * LNTO + 2.3649 * LNUP)$				
Case 3: Unrestricted Constant and No Trend				

Source: Author's calculation in EViews 10

The results displayed in table 8 indicate a positive and significant long-run relationship between total energy use and carbon dioxide emissions in Pakistan. It is observed that the high amount of energy consumption is directly linked with the emissions of greenhouse gases. According to the findings, the amount of 1% increase in energy consumption enhances the emissions of CO₂ by 0.97 % in the country. The positive and significant relationship implies that an increase in the total energy consumption in the form of biomass (animal products, gas, and liquid extracted from biomass) and industrial waste would lead to the enhancement of CO₂ emissions in the country. The results of this analysis for the long-run relationship between total energy usage and CO₂ emissions are consistent with those of [10, 11, 23-27].

The long-term association between the gross domestic product and CO₂ emission is positive but insignificant in Pakistan. The results of this analysis are inconsistent with those of [10, 23-25].

Similarly, the long-term association between industry-value added and CO₂ emission is negative but insignificant in Pakistan. This result is consistent with those of Lin et al. [28].

Moreover, the long-run relationship between urban populations is also positive and significant in Pakistan. The results of long-run coefficients indicate that the 1% rise in the urban population increases the CO₂ emissions by 2.36% in the country. Due to enhancement in the urbanization, energy demand will boost up in regards to housing, business units, transportation, and services industry. This condition will lead to high energy consumption, which will ultimately increase CO₂ emissions. The results of this study for the causal relationship between urbanization and CO₂ emission is consistent with the findings of [10, 11, 24, 27].

It is indicated from the results that the long-term association between trade openness and the emission of CO₂ is positive and significant in Pakistan. The finding shows that a 1% increase in trade openness increases the CO₂ emissions by 0.17% in the country. Trade openness in this study is the total sum of imports and exports. An increase in exports & imports enhances economic activities and mobilizes the business units to produce more by consuming high energy in the production processes. As discussed earlier in this section more energy consumption means more greenhouse gas emissions. Thus enhancement in trade openness increases CO₂ emissions. Our results support the studies of Wheeler and Martin-Vide[29], and Krueger [30]. However, the long relationship between financial development and CO₂ emissions is insignificant. Dogan and Turkekul, [31] analysis supports our insignificant result for the long-run relationship between the two variables.

The long-run relationship between financial development and CO₂ emissions is insignificant. Dogan and Turkekul, [31] analysis supports our insignificant result for the long-run relationship between the two variables.

According to ARDL long-run estimations, the major contributor to CO₂ emissions in Pakistan is the enhancement in urban population, followed by high energy consumption and an increase in trade openness, respectively.

Autoregressive Distributed Lag Model-ECM estimations

The ARDL-ECM Short-run estimations are presented in table 9.

Table 9

Autoregressive Distributed Lag Model-Error Correction Model short-run estimates

ECM Regression				
Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.06493	1.536244	-8.504465	0.0000
D(LNGDP)	-0.069164	0.078113	-0.885429	0.3832
D(LNINDUST)	0.060062	0.070338	0.853905	0.4002
D(LNTO)	0.020380	0.046275	0.440417	0.6629
D_92	-0.050119	0.007942	-6.310337	0.0000
CointEq(-1)*	-0.958058	0.112371	-8.525849	0.0000
Case 3: Unrestricted Constant and No Trend				

Source: Author's calculation in EViews 10

Table 9 reveals that the value of the error correction term is negative and significant, which is the indication of the long-run relationship between the emissions of CO₂ and its explanatory variables in Pakistan.

The error correction term measures the correction of fluctuation of the short-run from the long-run equilibrium; this correction of deviation of a short-run from a long-run, towards the long-run equilibrium is called the speed of adjustment. The speed of adjustment or correction of short-run deviation from the long-run equilibrium is 95% each year in Pakistan.

The findings of short-run coefficients are persistent with those of long-run for the relationship between gross domestic product and CO₂ emissions; industry-value-added and CO₂ emissions. The short-run coefficient for the relationship between trade openness and CO₂ emissions is positive but significant, which is inconsistent with the long-run coefficient for the two variables.

The short-run coefficients for the relationship between financial development and CO₂ emissions; energy use and CO₂ emissions; and urban population and CO₂ emissions are eliminated due to its optimal lag length of zero in selected ARDL (1, 0, 0, 1, 1, 1, 0).model.

Diagnostics tests:

The results of diagnostic tests for ARDL and ARDL-ECM are listed in table 10.

Table-10 Diagnostic test statistics

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.069104	Prob. F(1,28)	0.7946
Obs*R-squared	0.100939	Prob. Chi-Square(1)	0.7507
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.702431	Prob. F(11,29)	0.1228
Obs*R-squared	16.08734	Prob. Chi-Square(11)	0.1379
J-B normality test			
Jarque-Bera	1.639052		
Probability	0.440640		

Source: Author's calculation in EViews 10

Table 10 contains the results of the LM test for serial correlation, Breusch-Pagan-Godfrey test for heteroscedasticity, and J-b test for normality. The results LM test for serial correlation reveals that the probability value (0.75) of the Obs*R-squared is higher than the 0.05 level, which indicates to accept the null hypothesis of no serial correlation in the residuals. Similarly, the Godfrey test for heteroscedasticity indicates that the probability value (0.13) of the Obs*R-squared is higher than the 0.05 level, which validates to acceptance of the null hypothesis of homoscedasticity. J-B test for normality confirms the normal distribution of the data as the probability value (0.44) of J-B test statics is greater than the 0.05 level of significance, which indicates to accept the H_0 of normal distribution. The plots of CUSM and CUSM square (Appendix-E) also lie within the boundaries of 5% significance level.

It is concluded the ARDL and ARDL-ECM passed all the post-estimation diagnostic tests, which indicates that its estimations are valid and robust.

5. Conclusion And Recommendations

5.1. Conclusion

The main purpose of this study is to analyze the relationship between economic growth (GDP per capita) and CO₂ emissions within the theoretical framework of extended Dietz and Rosa's Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) Model. Very few studies are conducted to investigate the possible impact of economic growth (GDP per capita) on CO₂ emissions in Pakistan. Moreover, these studies ignore the combined effects of other major contributors to CO₂ emissions, in the country. This study overcomes these limitations by employing an extended STIRPAT model that studies the impact of GDP on CO₂ emissions, with the inclusion of major explanatory variables; industry value-added, total energy use, financial development, trade openness, and urban population into the analysis.

Elementary data analysis; Descriptive statics computation and Correlation; are conducted to examine the statistical properties of the data. The econometric analysis is performed by employing the Augmented Dickey-Fuller unit root test, Philips Perron Unit root test, and Zivot-Andrews root test, and Autoregressive Distributed Lag model, Error Correction Model, and Hatemi-J cointegration test with two unknown structural breaks. The ARDL-Bounds test approach is used to analyze the cointegration among variables. However, to increase the robustness of the findings in the presence of structural breaks, the Hatemi-J cointegration test is also incorporated. The ARDL model with structural breaks is used to estimate the long-run relationship between CO₂ emissions and explanatory variables; GDP, energy use, financial development, trade openness, and urban population. The short-run estimations are performed by employing the Error Correction Model within the methodology of ARDL.

The key results of the study are as follows:

1. Gross domestic product has a positive and insignificant relationship with CO₂ emissions in the context of Pakistan.
2. Industry, value added has an insignificant relationship with CO₂ emissions in the country.
3. The total energy use has a positive and significant relationship with CO₂ emissions in the country.
4. The urban population has a direct relationship with CO₂ emissions in Pakistan.
5. The long-run relationship between financial development and CO₂ emissions is insignificant in the country.
6. Trade openness has a long-run positive relationship with CO₂ emissions in the country.

5.2. Policy Recommendations

Based on the results this study has the following relevant policy recommendations:

1. The gross domestic product shows a positive but insignificant relationship with CO₂ emissions in Pakistan. It implies that with the increase in GDP per capita, the CO₂ emission also increases in the country. Therefore, it is required to adopt economic policies that promote clean production which will reduce the CO₂ emissions caused by the increase in GDP per capita.
2. However, the industry value added has an inverse and non-significant relationship with CO₂ emissions in the country, which is a good sign, as the results imply that enhancement in industry-value addition improves environmental quality in the country.
3. The relationship between trade openness and CO₂ emissions is positive and significant in Pakistan. The result implies that expansion in trade (exports plus imports) increase the CO₂ emissions in the country. An increase in exports & imports enhances economic activities and mobilizes the business units to produce more by consuming high energy in the production processes. More energy consumption increases greenhouse gas emissions, which in turn leads to an enhancement in CO₂ emissions. Therefore, these countries require adopting export and importing policies that are aligned with environmental protection and sustainability.

4. The relationship between financial development and CO₂ emissions is positive and significant in the country. It infers that when financial development increases the CO₂ emissions increase. This result implies that the banks' domestic credit giving criteria are not aligned with the protocol or guidelines of environmental stability. Therefore, the country requires adopting credit-giving policies, which are aligned with sustainable environmental practices.
5. The relationship between urban population and CO₂ emissions is positive and significant in the country. This is because, at the early stages of urbanization, people rush into the urban area and utilized the available energy resources without any environmental considerations, which enhances the CO₂ emissions. Moreover, the process of urbanization accelerates the economic activities which compel the firms to produce more in a competitive environment. As discussed earlier the more production is linked with more consumption of energy. And more energy is consumed more greenhouse gas (CO₂) emissions expel out to the environment. Therefore the country requires urban policies that are aligned with the compact city theory and ecological modernization theory, according to which the urban cities go through a social and institutional transformation in favor of environmental improvement. Moreover, the shift towards a piece of knowledge and service-based economy from agricultural orientation might also reduce CO₂ emission in a long run.
6. Energy used prevails a significant positive relationship with CO₂ emissions in Pakistan. It implies that the primary energy consumption in the shape of; biomass, animal products, gas, and liquid extracted from biomass, and industrial waste are the major contributors to the CO₂ emissions in the country. Therefore policy shift from nonrenewable energy resources (burning of biomass) towards renewable resources (solar, wind, and hydro energy) is required to alter the adverse effect of total energy use on the environment; CO₂ emissions.

Declarations

Availability of supporting data

The supporting data is available and will be provided upon demand.

Competing interests

We have no competing interests.

Funding

This research was not funded and the work is done with our own resources.

Authors' contributions

Introduction and literature review has been done by Tariq Rahim.

Data estimation is done by Syed Aziz Rasool.

Analysis and proof reading has been done by Muhammad Ali Khan.

Acknowledgements

We are thankful and acknowledge the support and environment provided by SZABIST University Islamabad which helps us conducting this research.

Authors' information

Dr. Syed Aziz Rasool, Assistant professor at Department of Social Sciences, SZABIST University, Islamabad, Pakistan

Tariq Rahim, MS Scholar at SZABIST University, Islamabad, Pakistan and Muhammad Ali Khan, Lecturer at SZABIST University, Islamabad, Pakistan

Furthermore, it is also stated that:

- The independent project is the result of our own independent work and investigation, except where otherwise stated.
- All verbatim extracts have been distinguished by quotation marks and the sources of my information have been specifically acknowledged.

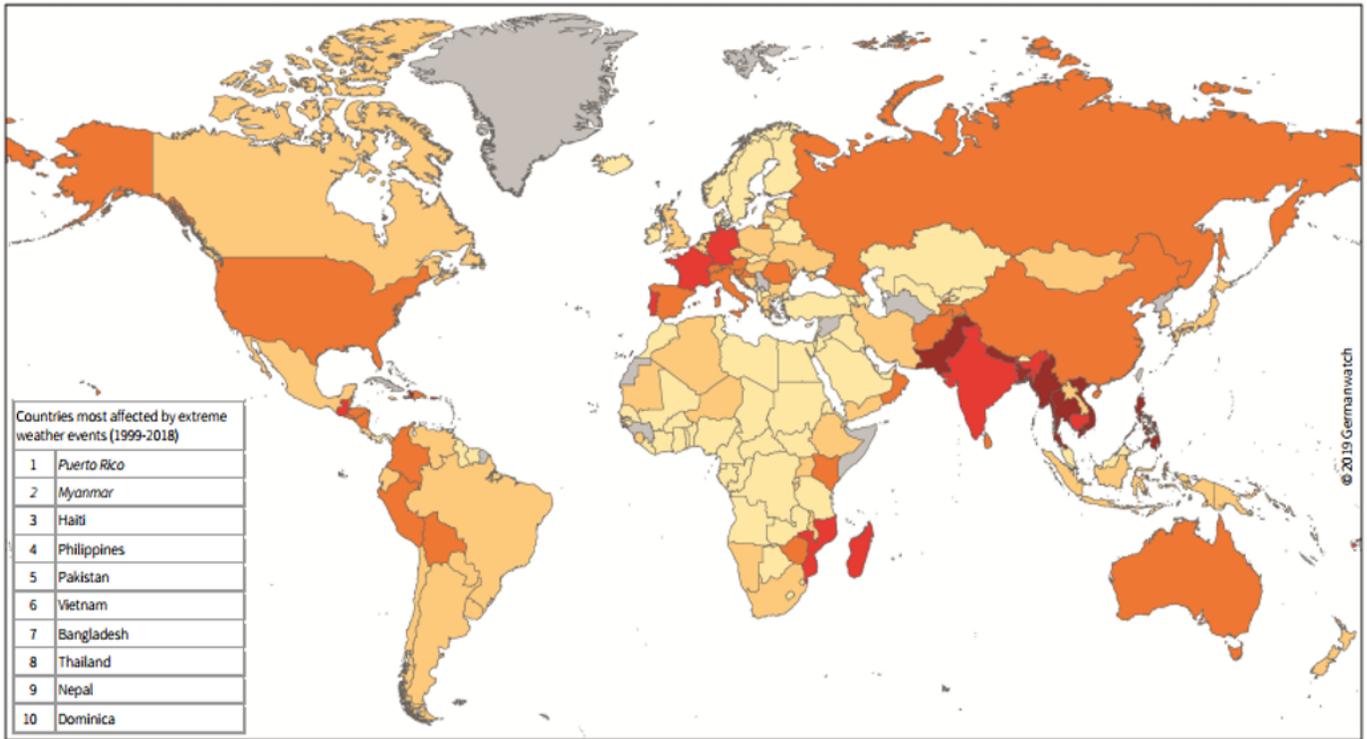
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Figures



Italics: Countries where more than 90% of the losses or deaths occurred in one year or event

Climate Risk Index: Ranking 1999 - 2018

1 - 10

11 - 20

21 - 50

51 - 100

>100

No data

Activa
Go to Pr

(Source: German watch, 2020)

Figure 1

Climate Risk Index

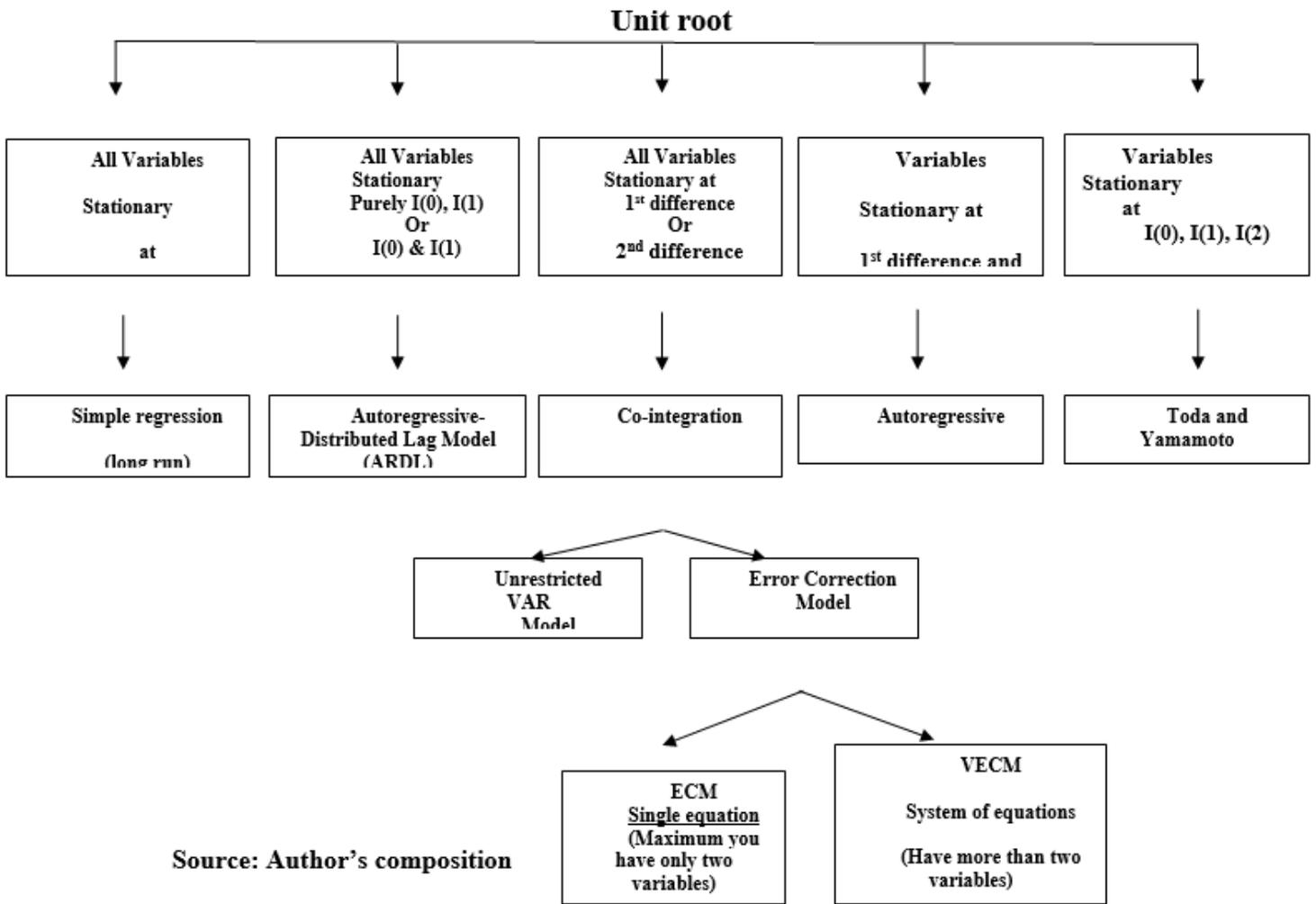


Figure 2

Econometric Model selection for time series based on data Stationarity

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