The effect of GDP, Gross fixed capital, Energy use and urban population on Carbon Emissions

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Abstract:

In this paper we have studied the presence and way of Granger causality among GDP, GFCF, Urban population, Energy use and CO2 emission in Pakistan, putting on a model of GDP, Carbon emissions, Energy use, GFCF and Urban population (P) that is multivariate. Result of Data of Pakistan over the period 1990-2020 suggest that GDP (Y),GFCF (GFC) and Urban population (P) Granger causes the Carbon emission in long run. That their increase will bring about an increase in carbon emission. P also Granger causes the Y which Granger Causes CO. Government of Pakistan can apply the polices to decrease carbon emissions by reducing the urban population in Pakistan.

Keywords: Carbon emission, GDP, Energy Use, Urban population, Gross fixed Capital Formation, Granger Causality

1. Introduction:

Global warming is one of the most serious environmental problems of our time. The continual rise in carbon dioxide (CO_2) levels, which is a major cause of the greenhouse effect, seems to be making things worse. Experts and researchers have been debating how to reduce greenhouse gas emissions and solve this problem.

Research on the connection between environmental pollution and economic growth falls into three main areas. The first area focuses on the Environmental Kuznets Curve (EKC) hypothesis, which shows an inverted U-shaped relationship between environmental degradation and economic growth. According to this hypothesis, environmental damage increases in the early stages of economic growth but starts to decrease after achieving a certain income level. This concept was introduced by Grossman and Krueger in 1991, who conducted broad research on it, but the results have often been debated. Critics argue that the EKC model doesn't account for how environmental degradation impacts economic growth because it treats income as an independent variable. Prominent researchers like Magnani, Stern, Inda, and Hill have reviewed these criticisms in detail.

The second area of research looks at the connection between economic growth and energy use, as burning coal is a major cause of pollution. Following the early work of Kraft in 1978, many studies have used Granger causality and cointegration methods to explore this relationship. Initial studies typically used simple models with only two variables, but these were criticized for missing crucial factors, which could lead to incorrect results. In 1993, Stern argued that these basic models might miss the effects of shifting between energy and other inputs. By using more complex models that include additional factors like capital and labor, Stern found evidence that energy use affects economic growth in the USA. However, even with more advanced models, later studies produced mixed results, as highlighted by reviews from Huang and others.

A third, more recent area of research combines the two earlier approaches to study the connection between energy use, environmental impact, and the economy over time. This dual approach aims to provide a more complete picture of how these factors interact, addressing the limitations of previous studies that examined these relationships separately.

In a 2007 study, Soytas et al. used a multifactorial model—including variables such as income, energy consumption, carbon emissions, capital formation, and labor force—to explore the relationship among these factors in the United States. Their findings showed no direct cause-and-effect relationship (Granger causality) between carbon emissions or energy use and income. However, they found that in the long run, energy consumption influences carbon emissions.

In 2009, Soytas and Sari repeated this analysis for Turkey and found similar results, except that in Turkey, carbon emissions affected energy consumption in the long run. This suggests that while both Turkey and the U.S. can control CO_2 emissions without significantly slowing their economic growth, the methods behind these changes may differ in each country.

In 2009, Halicioglu applied a unique method known as bounds testing to investigate the link between carbon emissions, energy use, income, and foreign trade in Turkey. His outcomes showed a two-way relationship between carbon emissions and income, meaning both variables affect each other in the long and short run. This result contrasts with the findings of Soytas and Sari (2009), who found only one-way causality.

Ang (2008) studied Malaysia and found that economic growth caused an increase in energy consumption, but there was less reliable evidence that CO_2 emissions affect income in the long run. No feedback connection was found between them.

Fewer studies have been conducted in China, but some of the conditions also apply to Pakistan. There are limited studies on how economic growth affects environmental damage and how this impact increases CO_2 levels. Song et al. (2008) found a long-term relationship between GDP and three types of pollution (waste gas, wastewater, and solid waste), showing an inverse U-shaped relationship. Yuan et al. (2008) found a link between GDP and energy use in the long term and that GDP influences energy use in the short term.

Pakistan, a developing country in South Asia, is experiencing rapid economic growth, and its economy is based on agriculture. However, industrial growth is reducing farmland. The increasing population rate has led to deforestation. Pakistan is one of the top countries in Asia facing these challenges.

Economic and industrial growth in Pakistan relies on traditional energy resources, which contribute to environmental degradation. Wolde-Rufael and Menyah (2010) highlighted that using traditional energy releases CO_2, worsening environmental quality. Ahmed et al. (2010) noted that environmental damage affects health in Pakistan. Yang and Lie (2017) pointed out that greenhouse gases like CO_2, nitrous oxide, and methane contribute to environmental harm. Shahbaz et al. (2013)

stated that using fossil fuels and factory emissions negatively impact the economy, agriculture, and forestry.

Studies by Chaudhry (2010), Pao and Tsai (2010), and Siddique (2004) explored the connection between energy use, economic growth, and environmental sustainability, mostly in developed countries. These studies often concluded that economic growth and energy consumption increase CO_2 emissions.

Research shows that understanding the relationship between economic growth, non-renewable energy, and CO_2 emissions is significant for developing countries like Pakistan. Countries with natural resources can reduce their reliance on fossil fuels and lower emissions. Balsalobre et al. (2018) suggested that energy policies can help decrease dependence on non-renewable energy.

This research aims to explore the relationship between energy consumption, CO_2 emissions, GDP, gross fixed capital formation, and urban population in Pakistan. It uses the unit root test, structural break ZA test, and diagnostic tests. It also includes the Granger causality test, working with variables that are stationary at different levels and allowing different lags in the variables. These findings will help policymakers develop effective strategies for promoting economic growth while protecting the environment.

2. Methodology:

Error correction model (ECM) and Vector auto regression (VAR) are frequently used to examine the granger reason among variables. The choice between methods depends on whether the variables in the question are stationary, integrated of order one (I (1)) or co-integrated. For example if the variables are I (1) and not co-integrated a Vector auto regression (VAR) model in first differences is typically used. On the other hand if the variables are co-integrated an Error correction model (ECM) is applicable. As it accounts for both short term and long term relationships. However pre-tests to determine whether variables are stationary, integrated or cointegrated are often sensitive to certain parameters, especially when working with small data samples. As shown by Toda (1995) such pre-tests in Johansen-Type" Error correction model (ECM)" can lead to significant biases in causality analysis. Similarly if the data contain unit ββββroots standard Wald tests used in level Vector auto regression (VAR) models may produce unreliable results because the distributions of the rest statistics become non-standard and depend on nuisance parameters (see sim et al, 1990 and Toda and Philips, 1993).

Toda & Yamamoto in 1995 introduced augmented VAR approach which is real-world solution to this problem. It can be used regardless of whether the variables are stationary or integrated making it very flexible. According to Zapata and Rambaldi (1997), this method is particularly powerful for moderate to large sample sizes. It ensures that even if there is ambiguity about if the variables are stationary (I (0)) or integrated (I (1)) results are still valid. Yamada and Toda (1998) compared this method with others such as FM-VAR (Philips, 1995) and ECM approaches, and found that while those methods may be more powerful in some cases they are prone to size distortions (I.e. incorrect rejection of the null hypothesis). On the other hand the TY procedure provides more stable results, making it an appealing choice when small size distortion is important.

For these reasons, studies like those by Soytas et al. in 2007 and Soytas and sari in 2009 have applied the TY procedure to analyze the relationship between energy use, income and environmental factors as in the case of china. This methods ability to handle uncertainties in data integration makes it highly suitable for such analyses.

The equation of our model is:

$CO = \alpha + \beta_1 Y + \beta_2 GFC + \beta_3 EU + \beta_4 P$

3. **Data & Unit Root Test:**
   3.1 Discussion & Data

We have taken the time series data for Pakistan

We use annual data on GDP(Y) and gross fixed capital formation (K) (both in constant LCU), Energy use (EU) (kg of oil equivalent per capita), CO2 emission excluding LULUCF per capita (CO), and Urban population (P). All the data that is obtained from WDI is covering the period 1990-2020

Labor force is used as variable in the literature (e.g. Soytas et al. in 2007), and total population is also used in literature (e.g. Song et al. in2008). According to our info, they have not used the urban population as variable to examine the interaction between output, energy use, and carbon emissions. In this paper, we applied urban population instead of labor force (L) or total population (TP). The cause is below:

- Pakistan economy is a typical dual one. Although the percentage of rural population is decreasing due to industrialization, the rural population offsets the urban population. Under the family-based contracted responsibility people in rural area are employed by themselves and mainly engaged in agriculture or the primary industry. So collecting of data of labor force is very difficult in rural districts. Moreover, the primary industry contributes less and less to GDP, and second industry and tertiary industry, that is mainly focus on the urban areas, are main contributors to GDP in Pakistan. Therefore, the economic activities focus on urban areas.
- The government of Pakistan has taken an initiative for controlling the problem of growing population by giving awareness to families about family planning so the total population growth rate could be controlled. A rising number of rural people migrated to urban area due to economic development
- More and more people are moving to urban areas due to facilities and industrialization and due to this pollution is increasing from the use of resource like transports for traveling.

3.2. Unit root tests

For obtaining highest integration order (d) of variables, we run unit root test before applying TY process, checking the stationarity of variables. Three different unit root tests can be conducted, which are Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-PhillipsSchmidt-Shin (KPSS).

Table 1:

Unit root test results:

LEVEL		ADF
Intercept	Co	-2.074242(1)
	Y	-0.158406(1)
	GFC	-1.412812(1)
	EU	-2.493708(1)
	P	0.52599(3)
Trend and Intercept	CO	-3.343702(1)
	Y	-2.669886(1)
	GFC	-3.267822(1)
	EU	-2.715217(1)
	P	-5.935013(1)
1St Difference		
Intercept	CO	-4.447283(0)
	Y	-2.780289(3)
	GFC	-2.534078 (1)
	EU	-2.534078(0)
	P	-3.522057(1)
Trend and Intercept	CO	-4.447283(0)
	Y	-2.775380(3)

	GFC	-2.395665 (1)
	EU	-4.411158(0)
	P	-3.530375(1)
2nd Difference		
Intercept	Y	-4.723541(0)a
	GFC	-6.973070 (0)
Trend and Intercept	Y	-4.728690 (0)a
	GFC	-6.892750 (0)a

We have conducted ADF and this unit root test used in our study have a null hypothesis that the series has a unit root against the alternative of stationary. Lag Lengths are found with the help of AIC and in parentheses. Table 1 shows the results obtained by Unit Root Tests, which shows that the integration orders of all variables do not seem to be more then 2. So (d) is identified as 2.

With structural break Many macroeconomic time series are stationary variation around a deterministic trend function if possible change are done in intercept and slope (trend) we should consider the structural break when using unit root test but the standard unit test which is used, unable to test the stationarity of series having structural break. In 1992, Zivot and Andrews (ZA) developed a unit root testing procedure which permits for estimated break in the trend function in context to alternate hypothesis. Table 2 contains summarized results ZA Unit Test which we have used to test the order of integration of series. ZA test indicates that P series is I (0), CO and EU series is I (1), and Y and GFC series are I (2).

Table 2

Result from ZA Unit Root tests having structure break:

Series	T Value	P Value	Break	1st Difference t value	P value	break	2nd difference t value	P value	Break

CO	-4.618969	0.0966	2007	-5.458080	<0.01	2017	------------	-------	------
Y	-3.657011	0.5926	1996	-2.624877	0.9745	2019	-7.0076777	<0.01	2019
GFC	-4.801694	0.0590	2005	-4.596298	0.1031	2018	-9.040913	<0.01	2018
EU	-3.667376	0.5857	2010	-5.506823	<0.01	2007	-------------	-------	-------
P	-6.960997	<0.01	1995	-----------	---------	--------	-------------	-------	-------

4. THE CAUSALITY TESTS:

The slightly contradictory results in Table 1 indicate that all series are not integrated of the same order, so the TY procedure to test for Granger causality appears to be the most appropriate method. To apply TY procedure, the optimum lag length of VAR model has to be decided firstly. We conduct five different Lag length, that are (LR), (FPE), (AIC), (SC), and (HQ). The outcomes of the VAR Lag length selection are given in the Appendix. All shows that VAR has the optimum lag length = 1

Table 3

Equation	Adjusted R^2	J-B Test	B-G Test	ARCHLM	White Test	Ramsey Test
Co2	0.966788	0.041071	38.54259	1.865243	0.968300	2.148979
Y	0.999959	0.867273	5.275990	2.338277	0.227777	6.952468
GFC	0.988329	0.504945	6.302312	0.115132	0.585042	1.078772
EU	0.978683	0.294450	4.396242	17.33491	0.709900	1.998013
P	0.999996	0.882577	4.803538	1.083951	0.501358	0.001444

Table 3 contains summarized diagnostic test results. Adjusted R^2 values are a little lower than Unadjusted R^2 values. That's why, all equations' explanatory power is robust. Results of J-B test show that all residuals are normality. No autoregressive conditional heteroscedasticity is indicated by Lagrange multiplier tests, and for all equations White tests Show there is no heteroscedasticity. There is no serial correlation for all equations in 5% significance level according to the results of Breush-Godfrey test. Ramsey Reset test results indicate that functional form of model is correct.
The CUSUM & CUSUM of square tests, failed to confirm a stability violation. The unit circle the VAR (2) is stable with all unit roots. Satisfied by of VAR (3) diagnostics, we move to test of Granger Causality after obtaining satisfactory result from the diagnostics of VAR(3), the test results are given in Table 4.

The result in Table 4 shows that in the long run urban population (P), GDP (Y) and GFCF (GFC) Granger causes the CO emissions. That their increase will bring about an increase in carbon emission.

P also Granger causes the Y which Granger Causes CO. Government of Pakistan can apply the polices to decrease carbon emissions by reducing the urban population in Pakistan.

Table 4

Granger Causality Test Results:

Dependent V	CO	Y	GFC	EU	P
CO	-	3.76045*	6.34482*	0.27394	11.4759*
Y	0.45301	-	13.2411*	3.93746*	0.9302*
GFC	2.26296	0.05085	-	0.04947	0.41999
EU	0.28066	1.01191	3.43672	-	4.79755*
P	0.91833	2.36211	4.73976*	4.79171*	-

*= reject

5. Generalized Impulse response:

The Toda-Yamamoto (TY) method is used to test whether there is a long term cause and effect relationship between variables. However, this method doses not show how changes (or shocks) in one variable immediately impact another variable or how long these effects last in the short term. To analyze these short term effects we use the "Generalized impulse response function". Introduced by koop et al. (1996). Unlike traditional methods the GIRF solves the problem of overlapping influences between variables and give the more accurate results. The finding from the GIRF are shown in fig. Where we can see how shocks to one variable effect the others over time.

6. Conclusion:

By using the TY method & Generalized Impulse Response (GIRF). Our paper investigate the link among Co2 (carbon emission), GDP (Y), gross fixed capital formation (GFCF) and (P) urban population and energy Consumption (EU) for the Pakistan. The data is time series data and the time period of the data is 1990-2020. In our research Co2 (carbon emission) is dependent variable. It were found that co2 is significantly influenced by the GDP growth (Y), urban population and GFCF in Pakistan.

Indicating that economic development and urbanization, while important for growth, are contributing to environmental degradation. The outcomes of unidirectional Granger causality from GDP (Y) to Carbon emission tell us that the economics growth (Y) is directly increasing the carbon emission (CO). The relationship highlight the need for Pakistan to adopt sustainable economic policies. Economic growth is very important for making the living standards better and reducing poverty but the government should adopt green growth strategies to balance environmental objectives. More efficient method or policies should be promoted that are supporting low carbon industries and implementing cleaner production technologies are important steps in separating economics growth from carbon emission (Co). Furthermore, key contribution to GDP (Y) improving energy efficiency in industrial sectors and service sectors, which can help to lower Carbon emissions (CO). In short run the carbon emissions are not directly influenced by urban population shocks but their long term relationships are significant. This indicate the importance of addressing the indirect ways through which urbanization contribution to carbon emissions (Co). Government should improve rural infrastructure and providing incentives for distributed economic activities which can help to slow urban Migration. Family plaining initiative should be strengthened to control population growth (P). The findings highlights the need for a balance approach, and combining economic development with environmental sustainability. While the study give significant understandings, the limitation of data availability and sample size should be considered. Further research incorporating additional variables and regional disparities is recommended to enhance the robustness of these findings.

Appendix:

VAR Lag Order Selection Criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	65.93040	NA*	0.000819*	-4.271062*	-4.082469*	-4.211997*
1	66.21560	0.472058	0.000862	-4.221766	-3.986025	-4.147935
2	67.53565	2.093874	0.000845	-4.243838	-3.960949	-4.155241

Reference:

World Bank Indicator (WDI), Data Time series, Years (1990-2020), Country (Pakistan). https://databank.worldbank.org/source/world-development-indicators

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