A Long-Term Analysis of the Relationship between CO_2 Emissions, Patents, and Fossil Fuel Pricing: A Case Study of Pakistan

Ali Raza
PhD Scholar, Centre for Economic Research, Shandong University, Jinan (250100), P.R. China.
Email: ar2013pide@gmail.com

Abdul Razaque Larik
Associate Professor, Department of Political Science, Government College University Hyderabad, Sindh, Pakistan.
Email: razaq.larik@gcuh.edu.pk

Muhammad Shuaib Khan Pathan
(Corresponding Author) Assistant Professor, Department of Economics, Government College University Hyderabad, Sindh, Pakistan.
Email: dr.m.shoaib@gcuh.edu.pk

Received on: 16-07-2024 Accepted on: 18-08-2024

Abstract

This study examines the patterns of CO_2 emissions in Pakistan and how they relate to the pricing trends of the main fossil fuels (oil and natural gas) and the number of patents. With the aid of econometric approaches, the time series data from 1976 to 2020 is estimated, and a unit root test is carried out to confirm data stationarity. The study uses panel co-integration models to examine the long-term correlation between oil prices, natural gas prices, the number of patents, and CO_2 emissions. The findings demonstrate an important, long-term link between oil and natural gas prices, the quantity of patents, and CO_2 emissions. Besides, the long-term link between CO_2 emissions, the cost of fossil fuels, and patents is quadratic. The results of the Johansen co-integration analysis indicate both a short and long-term causal relationship between CO_2 emissions and oil/gas prices. According to the current study, increasing the number of patents and boosting the price of oil and natural gas may help Pakistan lower its CO_2 emissions, which greatly impacts the country's ability to meet its climate-related sustainable development goals.

Keywords: CO_2 Emissions, International Oil Prices, International Gas Prices, Patents, GEL Classification: P18, Q48, Q54, Q56, R11.

Introduction

The patents of any economy, along with global oil and gas pricing, are essential to reducing carbon dioxide (CO_2) emissions. While areas with a tendency of innovations and technology are in better positions to combat climate change, areas with low levels of innovation and technology likely to have more sensitive climate change situations (Li, Elheddad, & Doytch, 2021). In order to help countries, achieve their objectives, reduce pollution, and promote sustainable development, the international panel on climate change has proclaimed that wide, balanced, and integrated nonmarket measures are necessary. In reality, though, either options result in comparable outcomes, or a combination of both has frequently led to historical accelerations of invention and expansion. Long-term, both domestic and international discoveries and research as well as technology transfers could lead to technological advancement (Oyebanji, Castanho, Genc, & Kirikkaleli, 2022).

The domain of environmental concerns has received revived consideration in the current decade as a result of climate challenges connected with growing pollution and environmental dilapidation at the hands of human race. An unheard-before level of global warming has been observed since 2000. Several scientists argue that rising amounts of CO_2 emissions as a greenhouse gas (GHG) add considerably to global warming and climatic instability (Lotfalipour, Falahi, & Ashena, 2010). A study from the Joint Research Centre of the European Commission indicates that using fossil fuels is one of the main causes of global CO_2. The Kyoto Protocol and the Paris Climate Agreement were enacted by countries all over the world to reduce GHG emissions in order to combat the growing environmental damage (Rasheed, Haseeb, Adebayo, Ahmed, & Ahmad, 2021).

The world's energy consumption is significantly influenced by rapid economic expansion, population increase, rising living standards, and infrastructure investment growth. Global demand for energy has increased over the past thirty years as a result of industrialized economies' growing industrialization. World Development Indicators database (2019) suggests that this procedure resulted in an increase in global energy consumption of almost 60%. Fossil fuels account for 82 percent of the world's overall energy usage. By 2014, OECD nations accounted for 38% of the world's total energy consumption. Nearly 88% of the energy used in OECD nations originates from conventional nonrenewable sources of energy like coal, natural gas, and oil. This has led to a considerable rise in CO2 emissions, which are thought to be the primary cause of GHG emissions. The OECD countries are responsible for one-third of the world's carbon emissions, which have climbed by around 63% during the past three decades. These emissions are thought to be the primary cause of significant environmental issues including climate change and global warming that threaten the entire world. Due to these widespread environmental catastrophes, nations are under intense political and social pressure to cut back on carbon emissions (Erdogan, Okumus, & Guzel , 2020).

The Environmental Protection Agency (EPA) reports that the amount of CO_2 emitted globally from fossil fuels has increased significantly since 1900. Since 1970, the amount of CO_2 released into the atmosphere has increased by over 90%. Around 78% rise in GHG emissions between 1970 and 2011 was caused by emissions from industrial processes and the combustion of fossil fuels. While in Pakistan From 1960 to 2021, CO_2 emissions were 84077.99 KT on average, with recorded high of 219792.45 KT in 2021 and recorded low of

14154.62 KT in 1960.

Approximately 90 percent CO_2 emissions are caused by the consumption of fossil fuels and cement production while Deforestation and other anthropogenic activities have share 10 percent (Li, Fang, & He, 2019). Crude oil, one of the main commodities and fuels in the world, is essential to the functioning of the current economic system. In particular, there is little doubt that the price of crude oil can exert an effect on businesses, which make up the system's main building block. Decarburization, on the other hand, emerges as an important and urgent solution to deal with the ongoing economic and environmental issues brought on by climate change as threats from the climate change increase. The global low carbon road's unifying objectives are to reduce carbon (dioxide) emissions while promoting economic growth.

As far as Pakistan is concerned, fossil fuel burning for energy production is the main cause of CO_2 emissions in Pakistan. The nation produces a considerable amount of its electricity using coal, natural gas, and oil, which results in significant carbon emissions. Various sectors such as industrial, transportation and agriculture heavily relying on the consumption of fossil fuel. Moreover, the both patents quantity and quality is vital in case of any country but when we look into the both aspects of Pakistan, it does not look impressive as compared to other nations. So this study will highlight the severity of the consumption of fossil fuels and also lack of concentration on quantity of patents. In Pakistan, finding alternatives to fossil fuels is crucial for resolving issues such energy security, environmental concerns, economic diversification, energy affordability, sustainability, international commitments, and fostering technological innovation. It might open Pakistan's future to greater sustainability, resiliency, and prosperity.

Regression models are frequently used to analyses issues with energy and the economy, and research articles typically focus on the relationships between energy use, carbon prices, carbon emissions quotas, and other factors. However, there is no pertinent literature that specifically examines the three factors of actual carbon emissions, Fossil fuel prices, and Patents. As a result, this article used the Pakistan as an example to explore the transmission mechanism of volatility in a closed economy as well as the interactive links between Fossil fuel prices, Patents and carbon emissions using the VEC model. For determining if there was a co-integration link based on the VAR model and the VEC model, sample data from 1970 to 2020 in the Pakistan for primary energy carbon emissions, Fossil fuel prices and Patents were chosen.

The study's main objectives in this research were the following: It is critical to establish whether there is a co-integration association between the four variables before determining if there is a long-term equilibrium association.

In this backdrop, the research objectives of the current study are:

- To find the short and long-term relationship between CO_2 emissions in Pakistan and International Oil Prices.
- To find the short and long-term relationship between CO_2 emissions in Pakistan and international gas prices.
- To find the Number of patents’ influence on CO_2 emissions in the short and long term.

Literature Review

The majority of Pakistan's energy comes from nonrenewable sources (oil, coal, and gas), which are harmful to the environment. According to the long-term results, rising oil prices and economic expansion assist in reducing the CO_2 emissions produced by the transportation sector, while rising energy intensity, population density, and road infrastructure, with population having the greatest impact, all result in an increase (Zafar, Zaidi, & Rasool, 2019). During the recent decades, environmental concerns through energy use and economic growth were identified as a growing worry among scholars. Every country's economic growth is primarily driven by the industrial sector, which uses environmentally friendly energy and emits carbon dioxide that contributes to global warming (Ghasemi, Rajabi, & Aghakhani, 2022).

Real GDP-based economic development and CO_2 emissions have a one-way relationship that extends over both the long and short terms from the latter (CO_2 emissions) to the former (real GDP). Additionally, there appears to be a one-way causal link between the price of oil and economic development as well as a short and long -term positive impact, suggesting that African nations stand to benefit more from rising oil prices. At a substantial level of 1% for both long and short-term causalities, a two-way causal association between the energy consumption and CO_2 emissions of the African economy is also confirmed (Mensah, et al., 2019). The long and short-term confirmation of Pakistan's inverted U-shaped environmental Kuznets curve suggests that carbon emissions rise in proportion to economic development. As the economy expands after reaching a critical point, the level of carbon dioxide emissions starts to decline. Pakistan's economy is heavily dependent on fossil fuels, so they need not only explore for alternative energy sources but also raise the proportion of renewable and green energy sources in the overall energy system (Ali, Gong, Ali, Wu, & Yao, 2020). Long-term impact of energy use on CO2 emissions in the oil-dependent economy is discovered to be favorable and statistically significant. With reference to the economy of Ecuador, both the long and short-term causal impact of crude oil prices on the economy's energy consumption and CO_2 emissions carry positively statistical significance, demonstrating that increase in crude oil prices may result in more energy consumption as well as CO_2 emissions (Nwani, 2017).

Studies have shown a strong association between economic growth and CO_2 emissions. As countries develop and their economies grow, they typically consume more energy and use more resources, which leads to an increase in GHG emissions. This is particularly true for industrialized nations, which have historically been responsible for a large share of global CO_2 emissions. However, the association between economic growth and CO_2 emissions is not linear (Zaghdoudi, 2017). In some cases, countries can accomplish economic growth while reducing their GHG emissions. This can be done by boosting the use of renewable sources of energy, bringing expansion in energy efficient practices, and employing policies, which are aimed at encouraging sustainable practices.

As per (Pujols & Hovdahl, 2022) efficiency loss of 28% in public research funding and, according to existing studies, an efficiency loss of 48% in carbon pricing. When compared to first-best, these environmental policy limits result in a significant welfare loss (16.1 percent reduction in per-period consumption-equivalents) and it is better to combine environmental policy with patent policy when switching from outdated to modern technology is simple.

Moreover, increase in global emissions is what spurs technical innovation's contribution to reducing pollution. Technology innovation for reducing carbon dioxide mostly emphasizes the function of patents while neglecting trademarks. Innovated products, services, processes, or technology for reducing the effects of climate change are registered as trademarks and patents by businesses and industries. For the purpose of obtaining post-patent trademarks, industries should advance their environmental technology and manufacturing techniques. Individuals will be motivated to innovate if they are aware of its potential to protect the environment and make money (Khurshid et al., 2022).

With an emphasis on how their combined effects on reducing CO_2 emissions, this research paper examines the relationship between Pakistan's patent volume and the price of fossil fuels. By combining two previously unstudied components, this novel method sheds light on how they collectively affect environmental sustainability.

The study tries to identify potential correlations and consequences for CO_2 emission reduction measures in Pakistan by taking into account the pricing of fossil fuels along with patent quantities. The significance of this research rests in its thorough investigation of numerous variables, which have generally only been looked at separately.

Data and Methodology

In this study we used time series data from 1976 to 2020 for the case of Pakistan. Data for CO_2 is collected from the (OECD) while the data of international oil prices and gas prices real collected from the WDI Pink sheets. Furthermore, the data regarding patents are gathered through World Bank.

Explanation of Variables

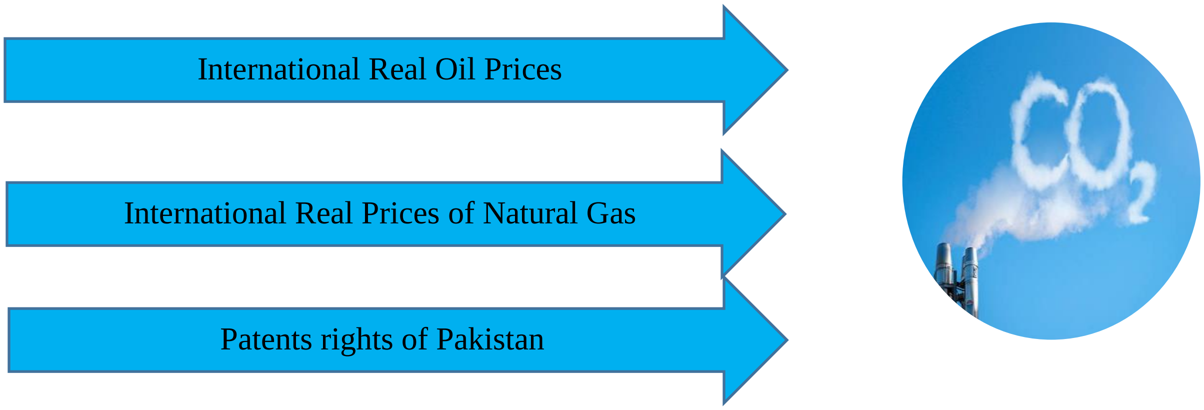
Model Specification

Variable	Description	Unit of Measurement
CO_2	As a dependent variable, carbon dioxide (CO_2) acts as the key component of the current study. They major purpose is to observe various factors affecting the CO_2 levels in a certain situation. By virtue of this analysis, this study aims to understand thoroughly the dynamics and impact of CO_2 emissions (Ca, Sam , & Chang, 2018).	MLN Tons
OilR	The treatment and analysis of global real oil prices, acting as an independent variable, serves as the key aspect. Consequently, the price of real oil on the international market is considered as a distinctive and important constituent that can affect CO_2.	USD
NGR	Another independent variable is the global natural gas real prices suggesting that the analysis of the effects of global natural gas real prices on CO_2 emissions remains the key aspect of the current study.	USD

P	The third independent variable is the number of patent rights in Pakistan. Employing it as a proxy variable, this study aims to investigate how technical innovation influences CO_2 emissions (Fortune, 2019).	Numbers

CO_2 Emissions = f (OilR + NGR + P)

CO2 emissions data is taken in the unit of (MLN_TONNE) million tone in Pakistan from 1976 to 2020, (Fabozzi , Focardi, Ponta, Rivoire, & Mazza, 2022) as the nominal variables cannot change the real variables so we took the real international oil and gas prices in USD. The third independent variable is patent rights.



In economies where there are greater number of patents rights, they tend to adopt more and more naïve technology which become the reason of low carbon emissions. Societies will always find their ways to adopt energy efficient ways, while the economies with lower number of patent rights will find difficulties in conversion from fossil fuels to green energy (Grubb et al., 2021).

Relationship of fossil fuels pricing is negative with the CO_2 emissions and the nations must switch from carbon-based energy sources to sustainable and consumer-friendly energy options due to volatile energy prices, supply chain vulnerability, and ecological effects of dwindling fossil fuels. The expansion of economies around the world is significantly influenced by energy capacities (Royal, Singh, & Chander, 2022). The nations are required to switch to non-conventional energy sources from conventional energy sources due to volatility in energy costs, energy reliability, ecological issues, energy security, and limited carbon-based energy supplies.

Innovative dimensions regarding the pattern of co-movements between oil shocks CO_2 emissions correlations across various frequency bands and scales are achieved by disaggregating oil price shocks into supply and demand shocks. Additionally, the study discover that rising oil prices brought on by shocks to the oil market and the global economy cannot replace environmental initiatives meant to cut carbon emissions (Kassouri, Bilgili, & Kuşkaya, 2022).

Results and Discussion

Empirical Results

To evaluate the stationarity of the CO_2, oil prices (OilR), natural gas prices (NGR), and number of patents (P) series, the widely used ADF (Augmented Dickey-Fuller) unit root test is employed.

The test findings, which are shown in Table.1, demonstrate that all three variables are non-stationary at the level; however, a further test reveals that the CO_2, OilR, NGR, and P variables are stationary at first-order difference. Regression analysis's initial step is to check for stationarity, and since none of the variables are stationary at level but are at first difference, the Johansen cointegration technique was used. We used this because, in the unlikely event that they had mixed order of integration, the variables were stationary at the time of application.

Table No. 1: Unit Root Test

At Level (Probability value)			At First Difference			
Series	With Intercept	With Trend and intercept	Series	With Intercept	With Trend and intercept	
Co2	0.9821	0.0570	Co2	0.0002	0.0005	I (1)
OilR	0.2224	0.5433	OilR	0.0000	0.0000	I (1)
NGR	0.3656	0.5410	NGR	0.0000	0.0000	I (1)
P	1.0000	0.9763	P	0.0000	0.0000	I (1)

In first step, we identify the level of stationarity where all of our variables are stationary at order one i.e. I (1).

To apply Johansson co-integration test, first, we have to select appropriate lag selection, i.e. until which lag should we check for co-integration. To check lags we apply are AIC, SIC and HQ methods.

Table No. 2: Lag Selection criteria

Lag order	AIC	SIC	HQ
0	33.88412	34.04313	34.04313
1	26.18654	26.98160*	26.98160*
2	25.67543	27.10654	27.10654
3	25.63479	27.70195	27.70195
4	25.29991*	28.00311	28.00311

In Table 2, SIC and HQ test identify first lag as most appropriate while AIC identified 4th lag as most appropriate lag length. We follow AIC method and will check co integration with 4 lags. Here we applied Johansen co integration test with following hypothesis.

The hypothesis is proposed as:

H0: No co integrating equation

H1: H0 is not true

Rejection of the null hypothesis is at 5% level.

Table No.3a: Johansson Co integration Test			
	Trace Stat	Critical Value	Prob
None	95.78346	47.85613	0.0000
At most 1	42.73581	29.79707	0.0010
At most 2	25.75656	15.49471	0.0010
At most 3	12.36722	3.841466	0.0004

From Table, Trace stat > Critical Value at None and Probability is less than 0.05 so Trace Test shows 4 co integration equations at 0.05 level

Table No.3b: Johansson Co integration Test			
	Max-Eigen State	Critical Value 0.05	Prob
None	53.04765	27.58434	0.0000
At most 1	16.97925	21.13162	0.1730
At most 2	13.38935	14.26460	0.0684
At most 3	12.36722	3.841466	0.0004

The null hypothesis that there is no co-integrating equation is rejected at the 5% level in light of the results obtained. Thus, it is inferred that there is a long-term association between the four factors. At the 0.05 threshold, the Max-Eigenvalue test shows one co-integration equation.

The Trace Test and Max Eigen Test are two test statistics that can be used to evaluate co integration when doing the regression Johansen test. The findings of both tests are shown in tables 3A and 3B.

VECM Estimates

Analysis and VECM estimation. Oil prices, natural gas prices, patent rights, and carbon emissions all exhibit long-run equilibrium linkages, but they are out of equilibrium in the near term, according to co integrated analysis. VECM serves as a convenient way to represent the dynamic structure and short-term imbalance. In light of this, an econometric software programs is used to establish the VECM model.

Included observations: 45 after adjustments	
Standard errors in ( ) & t-statistics in [ ]	
Cointegrating Eq:	**CointEq1**
CO2(-1)	1.000000
NGR(-1)	-214.2479
	(39.4026)
	[-5.43741]
OILR(-1)	2.462933
	(5.76221)
	[0.42743]
P(-1)	13.23053
	(2.98600)
	[4.43086]

C	-463.8650	

Error Correction:	D(CO2)	D(NGR)	D(OILR)	D(P)
CointEq1	-0.003557	0.000146	0.001096	0.035568
	(0.00153)	(0.00041)	(0.00452)	(0.00576)
	[-2.32251]	[0.35945]	[0.24246]	[6.17938]
D(CO2(-1))	0.166907	-0.048510	-0.493725	2.934093
	(0.17627)	(0.04663)	(0.52026)	(0.66251)
	[0.94691]	[-1.04035]	[-0.94900]	[4.42877]
D(CO2(-2))	-0.022524	0.092664	0.958345	0.747477
	(0.20658)	(0.05465)	(0.60974)	(0.77646)
	[-0.10903]	[1.69560]	[1.57172]	[0.96267]
D(CO2(-3))	-0.226410	-0.204938	-0.667758	-2.748242
	(0.27859)	(0.07370)	(0.82228)	(1.04711)
	[-0.81269]	[-2.78078]	[-0.81208]	[-2.62460]
D(CO2(-4))	-0.630988	-0.028384	-0.001478	3.581583
	(0.28444)	(0.07524)	(0.83953)	(1.06907)
	[-2.21838]	[-0.37723]	[-0.00176]	[3.35017]
D(NGR(-1))	-1.060678	0.002961	-0.144471	16.18948
	(0.94618)	(0.25030)	(2.79268)	(3.55627)
	[-1.12102]	[0.01183]	[-0.05173]	[4.55238]
D(NGR(-2))	0.158455	0.003829	-0.944297	-3.486495
	(0.94267)	(0.24937)	(2.78235)	(3.54311)
	[0.16809]	[0.01536]	[-0.33939]	[-0.98402]
D(NGR(-3))	-0.977792	0.415027	2.930518	14.24381
	(0.90897)	(0.24046)	(2.68286)	(3.41642)
	[-1.07572]	[1.72600]	[1.09231]	[4.16922]
D(NGR(-4))	-1.879334	0.236722	1.264165	9.333167
	(0.82100)	(0.21718)	(2.42321)	(3.08578)
	[-2.28909]	[1.08996]	[0.52169]	[3.02458]
D(OILR(-1))	-0.018610	-0.001027	0.114501	0.004464
	(0.07207)	(0.01906)	(0.21271)	(0.27087)
	[-0.25823]	[-0.05387]	[0.53829]	[0.01648]

D(OILR(-2))	-0.019623	-0.007392	0.112885	0.661875
	(0.07070)	(0.01870)	(0.20868)	(0.26574)
	[-0.27754]	[-0.39524]	[0.54095]	[2.49070]
D(OILR(-3))	-0.046486	-0.004933	-0.137369	-0.463905
	(0.07415)	(0.01962)	(0.21886)	(0.27870)
	[-0.62691]	[-0.25149]	[-0.62766]	[-1.66454]
D(OILR(-4))	0.079620	-0.039361	-0.329060	-0.366689
	(0.08168)	(0.02161)	(0.24109)	(0.30700)
	[0.97477]	[-1.82161]	[-1.36491]	[-1.19441]
D(P(-1))	0.104903	0.009345	-0.157732	-0.611842
	(0.05175)	(0.01369)	(0.15274)	(0.19450)
	[2.02720]	[0.68268]	[-1.03272]	[-3.14577]
D(P(-2))	0.185972	0.011247	-0.025330	-0.960527
	(0.05608)	(0.01483)	(0.16552)	(0.21078)
	[3.31626]	[0.75815]	[-0.15303]	[-4.55710]
D(P(-3))	0.064730	-0.001411	-0.055930	-0.524803
	(0.05584)	(0.01477)	(0.16482)	(0.20989)
	[1.15915]	[-0.09553]	[-0.33934]	[-2.50040]
D(P(-4))	0.088458	-0.001122	0.095857	-0.578768
	(0.04755)	(0.01258)	(0.14034)	(0.17872)
	[1.86034]	[-0.08920]	[0.68301]	[-3.23844]
C	3.485933	0.649643	2.635583	5.170303
	(1.47002)	(0.38887)	(4.33882)	(5.52517)
	[2.37136]	[1.67057]	[0.60744]	[0.93577]
R-squared	0.668255	0.564606	0.392998	0.831745
Adj. R-squared	0.459378	0.290469	0.010812	0.725807
Sum sq. resids	403.3757	28.22817	3514.057	5698.436
S.E. equation	3.865209	1.022491	11.40834	14.52767
F-statistic	3.199282	2.059578	1.028290	7.851234
Log likelihood	-113.1994	-53.35954	-161.9042	-172.7811
Akaike AIC	5.831083	3.171535	7.995741	8.479162
Schwarz SC	6.553748	3.894200	8.718406	9.201827
Mean dependent	3.245513	0.040198	0.723819	6.844444
S.D. dependent	5.256859	1.213875	11.47052	27.74392

Determinant resid covariance (dof adj.)	223438.3
Determinant resid covariance	28957.61
Log likelihood	-486.5647
Akaike information criterion	25.00287
Schwarz criterion	28.05413
Number of coefficients	76

Johansson Cointegration test

The appropriate choice of cointegration test form and lag sequence is the key to a successful co integration test. In the VAR model, the Johnsen (1988) and Juselius (1990) approach is typically used to scrutinize the cointegration connection between the variables. The chosen sequences in this case are linear trend terms, and the test form of the co integration equation is just the intercept. Given Table's findings, it is clear that two positive associations exist and that the trace and maximum eigenvalue tests support the null hypothesis under the 5% level for oil prices, natural gas prices, patents, and carbon emissions. This suggests that the variables are in long-term, stable equilibrium. Based on the hypothesis that there are connections between co-integration.

Included observations: 45 after adjustments				
Trend assumption: Linear deterministic trend				
Series: CO2 NGR OILR P				
Lags interval (in first differences): 1 to 4				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.692364	95.78346	47.85613	0.0000
At most 1 *	0.314301	42.73581	29.79707	0.0010
At most 2 *	0.257358	25.75656	15.49471	0.0010
At most 3 *	0.240297	12.36722	3.841466	0.0004
Trace test indicates 4 cointegrating eqn(s) at the 0.05 level				
*** denotes rejection of the hypothesis at the 0.05 level**				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.692364	53.04765	27.58434	0.0000
At most 1	0.314301	16.97925	21.13162	0.1730
At most 2	0.257358	13.38935	14.26460	0.0684
At most 3 *	0.240297	12.36722	3.841466	0.0004
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				
*** denotes rejection of the hypothesis at the 0.05 level**				
****MacKinnon-Haug-Michelis (1999) p-values**				
Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):				
CO2	NGR	OILR	P	
0.002658	-0.569432	0.006546	0.035164	

-0.001625	-0.592454	0.047949	-0.029660	
-0.063075	0.617800	-0.072130	0.058882	
-0.007129	0.037289	0.101111	-0.031853	
Unrestricted Adjustment Coefficients (alpha)				
D(CO2)	-1.338213	-0.146681	-1.323542	0.557413
D(NGR)	0.054789	0.120790	-0.094956	-0.361721
D(OILR)	0.412340	-3.249214	0.949366	-3.135845
D(P)	13.38243	-2.506870	-2.120475	-1.518139
1 Cointegrating Equation(s):		Log likelihood	-486.5647	
Normalized cointegrating coefficients (standard error in parentheses)				
CO2	NGR	OILR	P	
1.000000	-214.2479	2.462933	13.23053	
	(39.4026)	(5.76221)	(2.98600)	
Adjustment coefficients (standard error in parentheses)				
D(CO2)	-0.003557	Log likelihood	-478.0750	
	(0.00153)			
D(NGR)	0.000146			
	(0.00041)			
D(OILR)	0.001096			
	(0.00452)			
D(P)	0.035568			
	(0.00576)			
2 Cointegrating Equation(s):				
Normalized cointegrating coefficients (standard error in parentheses)				
CO2	NGR	OILR	P	
1.000000	0.000000	-9.371206	15.09068	
		(7.94288)	(4.42554)	
0.000000	1.000000	-0.055236	0.008682	
		(0.03481)	(0.01940)	
Adjustment coefficients (standard error in parentheses)				
D(CO2)	-0.003318	0.848922	-471.3804	
	(0.00179)	(0.47291)		
D(NGR)	-5.06E-05	-0.102761		
	(0.00047)	(0.12379)		
D(OILR)	0.006375	1.690209		
	(0.00493)	(1.29960)		
D(P)	0.039641	-6.135176		
	(0.00658)	(1.73488)		
3 Cointegrating Equation(s):		Log likelihood		
Normalized cointegrating coefficients (standard error in parentheses)				
CO2	NGR	OILR	P	
1.000000	0.000000	0.000000	0.114445	

			(0.30421)
0.000000	1.000000	0.000000	-0.079591
			(0.00951)
0.000000	0.000000	1.000000	-1.598112
(0.25371)			
Adjustment coefficients (standard error in parentheses)			
D(CO2)	0.080164	0.031238	0.079674
	(0.03259)	(0.53055)	(0.04483)
D(NGR)	0.005939	-0.161424	0.013000
	(0.00944)	(0.15373)	(0.01299)
D(OILR)	-0.053507	2.276728	-0.221575
	(0.09921)	(1.61503)	(0.13645)
D(P)	0.173390	-7.445206	0.120350
	(0.13081)	(2.12957)	(0.17992)

In conclusion, it is clear that short-term factors such as oil prices, natural gas pricing, and patents exert a significant effect on carbon emissions. Long-term, the impact is starting to level down. As shown in the model, both the current and lag-period variables are related to the growth of the price of oil and natural gas. The undervalued price of fossil fuels may encourage the use of more fossil fuel inputs and contribute to the efficiency of the market mechanism. Consequently, a key strategy to encourage the low-carbon transition would be to penalize the use of fossil fuels (Zou, 2018).

According to our analysis, taking action to adopt measures like boosting the prices of diesel, petrol and natural gas either by decreasing or eliminating subsidies, or by outright increasing the prices would significantly reduce demand in the medium and long terms. In nations like Pakistan, where diesel and petrol are often subsidized to a larger amount than petrol, this strategy is especially important.

This study argues that it may be predicted that these pricing changes are likely to exert a substantially less negative long-term effect on the demand for petro-products. Consequently, this decline in demand would help to significantly reduce CO_2 emissions, which may have a positive effect on the environment.

It can be argued that there are additional crucial factors to consider besides the immediate environmental benefits. For resolving concerns with resource allocation and financial restrictions, higher pricing for petro-products are essential. Inefficient resource allocation may be the result of subsidies for these fossil fuels that often pressurize public finances. These subsidies can be decreased or abolished, freeing up money for more eco-friendly and projects in renewable sources of energy.

Furthermore, the potential for both short and long-term demand reduction may inspire innovation and the usage of alternative energy sources. When traditional petro-product prices increase, consumers feel increasingly interested to examine and adopt more sustainable alternatives, for instance electric vehicles, renewable energy technologies, and energy-efficient practices. In addition to lowering CO_2 emissions, this shift to greener solutions would also encourage economic development and scientific improvements in the renewable energy industry. However, it is essential to perform these pricing changes after considering any potential socioeconomic impact. The shift to rising fuel prices should not excessively trouble low-income individuals; therefore, precautions should be taken to protect vulnerable people. Targeted support measures, such as income-based assistance or investments in the infrastructure of public transport, may be exercised alongside subsidy reform programs to reduce any negative impact.

The current investigation concludes that raising the price of diesel, petrol and natural gas, especially through the reduction or elimination of subsidies, has great potential for reducing consumption and lowering CO_2 emissions in the medium and long terms. Along with improving the environment, this strategy also solves problems with resource allocation, fosters innovation, and supports the use of sustainable energy sources. Careful planning and consideration for social and economic repercussions are essential to ensure a successful transition to a more sustainable future.

Conclusion

This study has developed a correlation model to observe the relationship between patent activity, CO_2 emissions, and the prices of oil and gas. Moreover, it attempted to employ the VECM to examine the causal associations between these variables. The study seeks to enlighten on the variables causing differences in CO_2 emissions by investigating these linkages.

A thorough evaluation of the associations between the cost of fossil fuels, the quantity of patents, and CO_2 emissions was performed using the correlation model created in this work. A more complete comprehension of these factors' interactions was reached by consider them all. The model studied both short and long-term consequences, allowing for a thorough assessment of the causal processes at work.

The results of this study indicate that the cost of petrol, the cost of oil, the quantity of patents, and CO_2 emissions have significant correlation. It shows that changes in these variables carry both short and long-term impact on CO_2 emissions. The VECM model-based study shows that changes in the price of oil, fuel, and the number of patents carry a significant effect on CO_2 emissions over the long and short terms. This finding is noteworthy taking into consideration the present economic and financial conditions in Pakistan, where increasing number of affording class are swapping from fossil fuel use to that of more eco-friendly sources like solar energy and other effective sources. The dependence on fossil fuels is reduced by the advancement in renewable energy sources, which also addresses the environmental degradation caused by their usage.

A promising development towards sustainability in the context of Pakistan may be witnessed in the improved use of green energy production methods, particularly solar energy. As public and corporations get sensitized of the economic and environmental advantages of renewable energy, they are widely adopting solar power as a practical and eco-friendly alternate for fossil fuel-based energy. Long-term cost cuts and cost diversification are also paybacks of this transformation, along with dropping CO_2 emissions.

Furthermore, the structure of renewable energy infrastructure, for example solar farms and wind turbines offers ventures for the economic development and jobs creation. The change to renewable energy sources inspires the development of a vibrant renewable energy industry, which may encourage technological improvements, attract funding, and produce job opportunities in the manufacture, installation, and maintenance industries related to renewable energy system.

The transition to renewable energy sources has favorable domino-effect along with the obvious environmental benefits. It reduces dependence on imported fossil fuels, increasing energy self-sufficiency and lessening susceptibility to price swings in the global oil market. Larger financial resources can now be directed more efficiently into other essential industries, for example infrastructure development, education, and healthcare.

The privileged class may have the resources to embrace renewable energy technologies, however other classes of society should have reasonable access to sustainable energy solutions. Government programs and endeavors can have an important role in maintaining the costs and availability of renewable energy options, mainly for underprivileged and rural populations.

In comparison to some other states, Pakistan's existing research and development (R&D) environment is lagging behind in producing high number of patents. Pakistan must prioritize R&D funding and focus on patentable technology for effectively addressing environmental emissions and implement policies that aim at CO_2 reduction.

The Government of Pakistan should encourage innovation and technical developments can potentially and significantly lessen environmental emissions by greater R&D fund allocation. Investment on R&D may allow investigating sustainable solutions for many industries, for instance waste management, energy, transportation, and agriculture. These endeavors can help develop innovative, efficient, and cost-effective eco-friendly technologies, procedures, and materials that. A substantial weight to patentable innovations may also offer Pakistan a competitive edge in the international market for green technologies. Pakistan can both protect its intellectual property and accelerate opportunities for direct investment and work together by develop patents for creative solutions. Patents demonstrate a nation's commitment to sustainable development and can encourage economic development, new job creation, and technological transfer. It is incumbent upon Pakistan to introduce supportive policies and measures to advance the R&D landscape and promote patentable technology by developing research grants and offering financial assistance programs, inspiring industry-academia linkages and extending financial incentives for private businesses and research institutes to invest in R&D.

References

1. Ali, M. U., Gong, Z., Ali, M. U., Wu, X., & Yao, C. (2020). Fossil energy consumption, economic development, inward FDI impact on CO2 emissions in Pakistan: Testing EKC. *International Journal of Finance & Economics*, 12.
2. Ca, Y., Sam , C. Y., & Chang, T. (2018). Nexus between Clean Energy Consumption, Economic Growth and CO2 Emissions . *Journal of Cleaner Production*, 35.
3. Erdogan, S., Okumus, I., & Guzel , A. E. (2020). Revisiting the Environmental Kuznets Curve hypothesis in OECD countries: the role of renewable, non-renewable energy, and oil prices. *Environmental Science and Pollution Research*.
4. Fabozzi , F. J., Focardi, S., Ponta, L., Rivoire, M., & Mazza, D. (2022). The economic theory of qualitative green growth. *Structural Change and Economic Dynamics*, 12.
5. Fortune, G. (2019). The impact of innovation and technology investments on carbon emissions in selected Organisation for Economic Co-operation and Development countries. *Journal of Cleaner*

Production, 57.

6. Ghasemi, M., Rajabi, M. S., & Aghakhani, S. (2022). Towards sustainability: The effect of industries on CO2 emissions. *Journal of Future Sustainability* , 12.
7. Grubb, M., Drummond, P., Poncia, A., McDowal, W., Popp, D., Samadi, S., . . . Pavan, G. (2021). Induced innovation in energy technologies and systems: a review of evidence and potential implications for CO2 mitigation. *Environmental Research*, 49.
8. Kassouri, Y., Bilgili, F., & Kuşkaya, S. (2022). A wavelet-based model of world oil shocks interaction with CO2 emissions in the US. *Environmental Science & Policy*, 12.
9. Khurshid, A., Rauf, A., Calin, A. C., Qayyum, S., Mian, A. H., Qayyum, S., & Fatima, T. (2022). Technological innovations for environmental protection: role of intellectual property rights in the carbon mitigation eforts.Evidence from western and southern Europe. *International Journal of Environmental Science and Technology*, 16.
10. Li, K., Fang, L., & He, L. (2019). The Impact of Energy Price on CO2 Emissions in China: A. *Science of the Total Environment*, 39.
11. Li, W., Elheddad, M., & Doytch, N. (2021). The impact of innovation on environmental quality: Evidence for the. *Journal of Environmental Management* , 14.
12. Lotfalipour, M. R., Falahi, M. A., & Ashena, M. (2010). Economic growth, CO2 emissions, and fossil fuels consumption in Iran. *Energy*, 6.
13. Mensah, I. A., Sun, M., Gao, C., Sasu, A. Y., Ampimah, B. C., & Quarcoo, A. (2019). Analysis on the nexus of economic growth, fossil fuel energy consumption, CO2. *Cleaner Production*, 27.
14. Nwani, C. (2017). Causal relationship between crude oil price,. *OPEC Energy Review* , 25.
15. Oyebanji , M. O., Castanho, R. A., Genc, S. Y., & Kirikkaleli , D. (2022). Patents on Environmental Technologies and Environmental Sustainability in Spain. *Sustainability*, 17.
16. Pathan, M. S., Ahmed, M., & Khoso, A. A. (2022). Islamic banking under the vision of green finance: The case of development, ecosystem, and prospects. International Research Journal of Management and Social Sciences, 3(1), 193-210.
17. Pujols, M. A., & Hovdahl, I. (2022). Patent Protection and the Transition to Clean Technology. 62.
18. Rasheed, M. Q., Haseeb, A., Adebayo, T. S., Ahmed, Z., & Ahmad, M. (2021). The long-run relationship between energy consumption, oil prices, . *Environmental Science and Pollution Research*, 14.
19. Royal, S., Singh, K., & Chander, R. (2022). A nexus between renewable energy, FDI, oil prices, oil rent and CO2 emission: panel data evidence from G7 economies. *OPEC Energy Review*, 20.
20. Zafar, M. W., Zaidi, S. A., & Rasool, Y. (2019). Determinants of carbon emissions in Pakistan's transport sector. *Environmental Science and Pollution Research*, 15.
21. Zaghdoudi, T. (2017). Oil prices, renewable energy, CO2 emissions and economic growth in OECD. *Economic Bulletin*, 8.
22. Zardari, M. H. A., Sohu, M. N. U., & Ali, S. J. (2022). Exploring Institutional Ecosystems in Modern Social Entrepreneurship: A Data-Driven Perspective. *International Research Journal of Management and Social Sciences*, 3(1), 306-337.
23. Zou, X. (2018). VECM Model Analysis of Carbon Emissions, GDP, and International Crude Oil Prices. *Discrete Dynamics in Nature and Society*, 12.