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Fiscal and Monetary Policy, Energy Consumption, and CO2 Emissions: Unveiling the Green Impact of Liberalization in Pakistan

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ABSTRACT

Objective: The paramount aim of this study was to determine the influence of fiscal policy, monetary policy, and energy consumption on CO2 emissions in Pakistan before and after liberalization.

Research Gap: None of the earlier studies to date have been organized to examine the influence of contractionary and expansionary fiscal and monetary policies, along with energy consumption and trade liberalization, on carbon emissions in Pakistan. This study contributes to the literature by determining the influence of fiscal policy, monetary policy, and energy consumption on CO2 emissions with reference to liberalization in Pakistan.

Design/Methodology/Approach: This study utilizes the correlated component regression methodology, which is more suitable for multicollinear data sets.

The Main Findings: Our findings illustrate that contractionary fiscal and monetary policies have an inverse influence on CO2 emissions during the pre-liberalization, with the former being insignificant and the latter significant. In the pre-liberalization period, expansionary fiscal policy has a significant and positive influence on carbon emissions, whereas expansionary monetary policy affects carbon emissions positively but insignificantly. In the post-liberalization period, both contractionary fiscal and monetary policies have a negative effect on CO2 emissions, while expansionary fiscal and monetary policies positively affect CO2 emissions. Electricity, oil, and coal consumption also have a positive influence on CO2 emissions during the pre- and post-liberalization periods, whereas the effect of natural gas consumption on carbon emissions is positive only in the pre-liberalization.

Theoretical/Practical Implications of the Findings: Based on our findings, the government should raise environment-related expenditures through expansionary fiscal and monetary policies to achieve fair and sustainable economies with low carbon emissions. The expansionary fiscal policy would be focused on green budgeting with special emphasis on environmental protection, targeting renewable energy, and promoting green infrastructure in manufacturing.

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1. Introduction

Climate change is an urgent and challenging global issue. It is a threat multiplier, affecting the most vulnerable populations and intensifying existing inequalities. Developing countries, where there are insufficient resources to tackle climate change, are affected more by climate change than developed countries. Pakistan, although contributing approximately 0.9% to global greenhouse gas emissions, is among the most negatively affected countries from climate change and air pollution. According to the long-run Climate Risk Index, Pakistan was identified as the 8th most adversely affected nation due to climate change from 2000 to 2019. During the period from 1999 to 2018, its position was even more worsened, placing it as the 5th most adversely affected country (Eckstein et al., 2021). Climate change requires immediate and collective responses worldwide to transform economies to low-carbon with sustainable growth. Krueger and Grossman (1991) introduced the idea of connecting economic development and environmental pollution, indicating that growth in GDP per capita increased pollution emissions at low income levels whereas diminishing environmental pollution at high income levels. Economic growth, in the absence of technological or structural change, would directly lead to an increase in pollution and other environmental degradation (Stern, 2004), which is referred to as the scale effect. Xue et al. (2021) found that environmental sustainability can be attained by enhancing economic growth, limiting fossil fuels and reducing foreign direct investment. Meanwhile, macroeconomic policies with the sole objective of economic growth would also negatively affect environmental quality. Specifically, during expansionary monetary policy, the central bank designs the monetary policy by increasing the money supply or reducing the bank rate. Fluctuations in interest rates would affect industrial energy consumption patterns, investment and aggregate demand, thereby causing more environmental pollution in the economy (Qingquan et al., 2020). In contrast, some studies in the literature highlight the significance of green monetary policy in reducing environmental consequences caused by expansionary policy. Green finance with rational market mechanisms can effectively allocate funds in mitigating environment-related risks and optimally allocate environmental and social resources (Wang and Zhi, 2016). After investigating this matter in China, He et al. (2019) concluded that green financial development increased the investment in renewable energy while it inhibited the bank loans in renewable energy companies. Meanwhile, Mughal et al. (2021) empirically investigated and demonstrated that contraction and expansion in monetary policies inhibited and enhanced emissions, respectively.

Regarding the influence of fiscal policy on environmental degradation, it is essential to understand the relationship between three components: government spending, economic performance, and environmental degradation (Oh, 2023). Economic theory provides a theoretical basis concerning the linkage between government spending and economic performance. As government spending, along with consumption, investment and net exports, is a crucial component of GDP, it is widely acknowledged that government spending is related to economic performance. Moreover, theoretical evidence regarding the linkage between government spending and the environment is shown for the ways in which fiscal spending can significantly influence the environmental quality. Fiscal policy instruments directly and indirectly affect the economy through aggregate demand, which in turn affects environmental quality through economic scale, industrialization, and energy consumption. Halkos and Paizanos (2013) analyzed and found that fiscal expenditure directly reduced per capita carbon and sulfur dioxide emissions. However, fiscal spending had a negative indirect effect on sulfur dioxide emissions at low income levels and a positive effect at high income levels, while it had a negative effect on carbon emissions at whole income levels. Grossman and Krueger (1995) explored that the initial phase of economic development increased environmental pollution, while it reduced environmental pollution when some critical level of income was reached. According to Ramlogan and Nelson (2024), expansionary and contractionary fiscal policies also have significant impacts on environmental quality. According to their findings, fiscal expansion mitigated the environmental quality through boosting economic performance and energy consumption, while contractionary fiscal policy inhibited carbon emissions due to slowing down the economic performance and reduction in energy consumption. In contrast, Halkos and Paizanos (2016) explored and authenticated that expansion in fiscal policy significantly alleviated consumption-generated and production-generated carbon emissions, while deficit-financed tax cuts increased consumption-based and production-based carbon emissions. Some academicians emphasized the role of carbon prices in mitigating the effects of global warming. For instance, Gaspar et al. (2019) proposed that climate change has now become a clear and current threat to the global economy. Its effects can be minimized by imposing carbon taxes on coal and other polluted fossil fuels. It would encourage economies to transition to clean energy sources. The authors further recommended that a carbon tax of $75 per ton of carbon emissions should be imposed on large-emitting economies to keep global warming to 2°C or below in 2030.

In addition to fiscal and monetary policies, some researchers also highlight the significance of energy use in affecting carbon emissions. Osobajo et al. (2020) authenticated that energy use had a significant and increasing influence on emissions. Soytas et al. (2007) empirically considered the linkages among pollution, income and energy use in the United States. Their findings demonstrated one-way causal links between energy use and pollution. Zhang and Cheng (2009) obtained similar results in China by establishing long-term one-way causality between energy use and pollution. In contrast, Zhou et al. (2018) analyzed and demonstrated that energy use escalated the pollution for both underdeveloped and developed nations. However, in developed nations compared to underdeveloped nations, energy consumption had a stronger influence on emissions. In Pakistan, Khan et al. (2019) authenticated that energy use, trade, financial development, social, political and economic globalization and FDI all have long-run impacts on environmental pollution.

The increasing trend of carbon emissions in recent years in many countries has sparked renewed interest among academicians to examine the influence of numerous factors, specifically focusing on how macroeconomic policies affect the emissions-generating mechanism. The nexus between energy consumption, monetary and fiscal policies and the environment has adopted the emerging interest in the literature. However, little research has analyzed the influence of contraction and expansion in fiscal and monetary policies, along with energy consumption, on CO2 emissions in Pakistan. Though no study to date has been organized to examine the influence of contraction and expansion in fiscal and monetary policies, along with energy consumption and trade liberalization, on carbon emissions in Pakistan. With this study, we will bridge this gap by determining the influence of fiscal policy, monetary policy, and energy consumption on CO2 emissions with reference to liberalization in Pakistan. In light of the present research gap, the primary objectives of the research described in this study are:

i. To determine if the expansion in fiscal and monetary policies results in increased CO2 emissions in Pakistan in the context of pre- and post-liberalization.
ii. To determine if the contraction in fiscal and monetary policies results in decreased CO2 emissions in Pakistan in the context of pre- and post-liberalization.
iii. To explore if the increase in disaggregated energy consumption results in increased CO2 emissions in Pakistan in the context of pre- and post-liberalization.

To analyze the above objectives, we utilized a correlated component regression technique, recently developed by Magidson (2013). The historical data from 1974 to 2020 is decomposed into two time windows: the 1974 to 1994 years, indicating the pre-liberalization period and the 1995 to 2020 years, representing the post-liberalization period. This division is based on the founding of the World Trade Organization in 1995, along with a substantial change in tariff structure in Pakistan. In Pakistan, before 1990, the tariff rate was 225%, which was further reduced to 70% in 1994-95. To some extent, this study contributes to filling the existing knowledge gap by determining how liberalization has affected CO2 emissions in Pakistan. To develop effective macroeconomic policies in Pakistan, it is necessary to understand the impacts of fiscal and monetary policies, along with energy consumption, on carbon emissions. Our findings will help to design strategies for creating a composition mix that is sustainable for developing economies like Pakistan.

2. Literature Review

Between 1998 and 2019, Bletsas et al. (2022) analyzed the impact of institutional quality, monetary policy and fiscal policy on CO_2 and GHG emissions while using a panel of 95 countries. Their results indicated that economic growth reduced the environmental quality, whereas government effectiveness, independence and transparency of the central bank and fiscal expansion improved the quality of the environment as they reduced emissions. Over the period of 1990-2018, Lau et al. (2024) probed that expansionary monetary policy, fiscal policy and technology had a negative influence on CO2 emissions. In contrast, population and economic growth significantly reduced the environmental quality as they increased the emissions. Bildirici et al. (2023) empirically examined and concluded that expansionary fiscal and monetary policies had significant and positive impacts on CO_2 emissions, whereas contractionary monetary and fiscal policies reduced environmental pollution. In Trinidad and Tobago, Ramlogan and Nelson (2024) investigated the effects of monetary and fiscal policies on CO_2 emissions using the dataset spanning from 1970 to 2020. Estimated results of the study authenticated that fiscal expansion significantly increased CO_2 emissions, whereas contraction in fiscal policy improved the environmental quality. In contrast, the monetary expansion increased environmental pollution, while monetary contraction significantly reduced emissions.

Ali et al. (2022) investigated and concluded that both land under cereal crops and agricultural land both had a significant and positive effect, whereas crop production index had an inverse effect on CO_2 emissions. Between 1965 and 2015 in Pakistan, Khan et al. (2020) empirically analyzed and demonstrated that oil and coal consumption contributed positively to CO_2 emissions both in the short and long run, while natural gas consumption and economic growth increased CO_2 emissions only in the short run. From 1990 to 2019, Mahmood et al. (2022) explored and suggested that fiscal policy contributed positively to both consumption- and territory-related CO_2 emissions, while the long-term impact of monetary policy on consumption- and territory-related emissions was negative.

In Pakistan, between the period of 1985-2019, Ullah et al. (2021) found a short-term inverse and positive shock in fiscal policy instruments contributed positively, while a long-term inverse and positive shock in fiscal policy instruments contributed inversely to carbon emissions. Moreover, a short-term inverse and direct shock in monetary policy instruments significantly increased the environmental degradation, while a long-term positive shock in monetary policy instruments significantly reduced the environmental pollution. From 1990Q1 to 2017Q4, Chishti et al. (2023) demonstrated that contraction in commercial policy improved the environmental quality by significantly reducing the carbon emissions, while expansion in commercial policy reduced the environmental quality by increasing the carbon emissions in the long run. Moreover, renewable energy consumption and exports contributed negatively to carbon emissions, while GDP per capita indicated a positive influence on carbon emissions. Between the period of 1994-2014, Osobajo et al. (2020) authenticated that energy consumption and economic growth both had a positive influence on carbon emissions. Gessesse and He (2020) showed that energy consumption and GDP had a positive long-run influence on carbon emissions in China. Chandia et al. (2018) determined the relation between energy consumption, economic performance and carbon dioxide emissions in Pakistan while considering data from 1971 to 2016. Findings authenticated that energy consumption and economic growth both contributed positively to carbon emissions in the long run. Gershon et al. (2024) investigated the connection between energy consumption, economic development, FDI, capital formation and carbon emissions in seventeen African nations while using data from 2000 to 2017. Empirical findings indicated that energy consumption and FDI showed an inverse influence on carbon emissions.

Wang et al. (2023) demonstrated that FDI had a positive influence on carbon emissions for both high- and low-middle-income countries, whereas its impact was inverse for upper-middle-income nations. Amoah et al. (2023) analyzed the influence of FDI on carbon emissions using panel data from 2000 to 2022 while considering a group of 30 sub-Saharan African countries. Empirical results suggested that FDI inflows showed a positive influence, while FDI outflows indicated a negative influence on carbon emissions. Wang and Huang (2022) studied the effect of trade openness, GDP per capita and FDI on carbon emissions in East Asian economies while considering data from 2011 to 2020. Results authenticated that GDP per capita, FDI, and trade openness all showed a significant positive effect on carbon emissions in selected East Asian countries. Yi et al. (2023) authenticated that FDI contributed negatively to carbon emissions in labor, capital and technology-intensive manufacturing industries. Kastratovic (2019) explored the influence of FDI on agricultural-based GHG emissions while covering data from 2005 to 2014 for 63 developing countries. The empirical results of the study authenticated that FDI showed a positive influence on GHG emissions in the agriculture sector. Mahmood (2012) studied and authenticated that FDI, manufacturing value added and population density showed a direct and significant influence on carbon emissions. Prakash and Sethi (2023) analyzed the influence of capital formation on carbon emissions using statistical data from 1971 to 2021 for the Indian economy. The whole dataset was divided between two time periods: before liberalization, indicating the period from 1971 to 1990 and after liberalization, representing the time span from 1991 to 2021. Empirical findings of the study found that capital formation showed a significant positive influence on carbon emissions for the period after the liberalization, whereas its impact was insignificant before the liberalization.

3. Theoretical Framework

Several studies have utilized the Cobb Douglas production function to analyze the effect of fiscal and monetary policy on CO2 emissions by assuming that production processes are the primary source of environmental pollution, including CO2 emissions. Studies by You (1981), Sinai and Stokes (1989) and Hasan and Mahmud (1993) emphasized that real money balances can be viewed as an important component of production. Incorporating this variable as an input to the Cobb Douglas production function can produce a more precise specification. As a result, the modified Cobb-Douglas production function that includes real money balances as an additional factor input can be expressed as follows:

$$Y = AK^{\alpha}L^{\beta}MP^{\gamma} \quad (1)$$

On the other hand, according to Stern (1997), Cleveland et al. (2000), Murphy and Hall (2011), energy is also a crucial factor of production. By incorporating energy as a factor input, equation (1) can be rewritten as:

$$Y = AK^{\alpha}L^{\beta}MP^{\gamma}E^{\delta} \quad (2)$$

Where Y, K, L, MP, E and A represent the output, physical capital, labor, real money balances, energy and total factor productivity, respectively. α, β, γ, and δ represent the percentage change in Y in response to a small percentage change in K, L, MP and E, respectively. A number of economists argue that the production processes are the primary source of environmental pollution, including CO2 emissions. Consequently, we replace Y with CO2 in equation (2) to derive the production-related pollution function:

$$CO2 = AK^{\alpha}L^{\beta}MP^{\gamma}E^{\delta} \quad (3)$$

In equation (3), we employ gross fixed capital formation (GFC) and population size (POP) as proxies of K and L, respectively. Energy (E) is disaggregated into four components: electricity consumption (EC), oil consumption (OILC), coal consumption (COALC) and natural gas consumption (NGC). Thus, the modified production-related pollution function is expressed as follows:

$$CO2 = GFC^{\alpha}POP^{\beta}MP^{\gamma}EC^{\delta 1}OILC^{\delta 2}COALC^{\delta 3}NGC^{\delta 4} \quad (4)$$

Many earlier studies have theoretically and empirically emphasized that monetary policy plays a significant role in determining the environmental quality (Faria 1998; Qingquan et al. 2020; Chishti et al. 2021; Liguo et al. 2022; Faria et al. 2023; Attilio et al. 2023). In the literature, monetary policy has been disaggregated into two types: contractionary monetary policy showing the decrease in money supply and expansionary monetary policy indicating an increase in money supply. Juhro and Rummel (2022) argued that contractionary monetary policy slowed down economic activity by reducing the money supply. Expansion in monetary policy, on the other hand, stimulated economic activity by increasing the money supply. Monetary authorities or the central bank, during expansionary monetary policy, use various tools, such as purchasing treasury notes, lowering the interest rates on loans to commercial banks and reducing the reserve requirement. Using these tools, monetary authorities increase the money supply and decrease interest rates, thus dwindling the cost of borrowing. These actions provide incentives for businesses to borrow more money for investment purposes and banks to issue more loans, thereby increasing consumer spending and firms' investments and therefore stimulating aggregate demand. An increase in consumer purchases and lower borrowing costs will create an incentive for firms across the country to invest more in equipment and machinery. Since new plants and machinery require more energy, this situation will lead to more CO2 emissions in the economy. During contractionary monetary policy, monetary authorities also utilize different tools, including selling treasury notes, increasing the interest rates on bank loans and increasing the reserve requirement. In this way, the central bank or monetary authorities reduce the money supply and increase the interest rates, thereby increasing the cost of borrowing. This discourages banks from issuing loans and businesses from borrowing, thereby reducing consumer purchases and investment and consequently contracting aggregate demand. A decrease in consumer spending and higher borrowing costs will discourage the firms from investing in plant and machinery. Energy sector enterprises also limit their investment due to higher borrowing costs, thereby decreasing CO2 emissions in the economy. Equation (4) can be adjusted to accommodate contractionary and expansionary monetary policies by decomposing MP into two variables: CMP for contractionary monetary policy or a negative change in MP and EMP for an expansionary monetary policy or a positive change in MP. Incorporating these monetary policy variables into equation (4) yields:

$$CO2 = GFC^{\alpha}POP^{\beta}CMP^{\gamma 1}EMP^{\gamma 2}EC^{\delta 1}OILC^{\delta 2}COALC^{\delta 3}NGC^{\delta 4} \quad (5)$$

In an economy, fiscal policy can also contribute to CO2 emissions and can be included in the pollution function. A number of previous studies have theoretically and empirically indicated that fiscal expenditure is an important determinant of environmental pollution (Lopez et al. 2011; Halkos and Paizanos 2013, 2016, 2017; Galinato and Islam 2017; Lau et al. 2024). These studies highlight the channels through which fiscal policy impacts environmental outcomes, particularly through changes in government spending and taxation. The literature categorizes fiscal policy into two ways: expansionary and contractionary fiscal policy. Expansionary fiscal policy stimulates aggregate demand in two manners (Weil, 2008). Firstly, the government boosts expenditures while leaving taxes unchanged, which immediately stimulates the aggregate demand. Secondly, the government reduces taxes or raises transfer payments, which boosts income and consumption and consequently aggregate demand. In order to meet this increase in aggregate demand, firms will produce more output. Higher output will require more energy use by the firms, and hence they will produce more CO2 emissions. In contrast, contractionary fiscal policy is described as a decline in government spending, a rise in taxes, or a decrease in transfer payments. These measures reduce aggregate demand through reductions in government expenditures or cuts in people's consumption. As a result, the firms will reduce their output and consume less energy, which leads to lower production of CO2 emissions. Equation (5) can be extended to accommodate contractionary and expansionary fiscal policies by incorporating two variables: CFP for contractionary fiscal policy or a negative change in government expenditure (FP) and EFP for an expansionary fiscal policy or a positive change in government spending (FP). Incorporating these fiscal policy variables into equation (5) yields the following equation:

$$CO2 = GFC^{\alpha}POP^{\beta}CMP^{\gamma 1}EMP^{\gamma 2}EC^{\delta 1}OILC^{\delta 2}COALC^{\delta 3}NGC^{\delta 4}EFP^{\theta 1}CFP^{\theta 2} \quad (6)$$

There are some other control variables that may affect the CO2 emissions. Inclusion of these control variables in equation (6) yields equation (7):

$$CO2 = GFC^{\alpha}POP^{\beta}CMP^{\gamma 1}EMP^{\gamma 2}EC^{\delta 1}OILC^{\delta 2}COALC^{\delta 3}NGC^{\delta 4}EFP^{\theta 1}CFP^{\theta 2}CV^{\rho} \quad (7)$$

In equation (7), GFC represents the gross fixed capital formation, POP indicates the size of the population, CMP and EMP specify respectively the contractionary and expansionary monetary policy, EC, OILC, COALC and NGC respectively indicate the electricity, oil, coal and natural gas consumption and EFP and CFP respectively show the expansionary and contractionary fiscal policy. Finally, CV includes three control variables, considering the gross domestic product (GDP), agricultural value added (AVA) and foreign direct investment (FDI). By incorporating these control variables into equation (7), we get the following equation:

$$CO2 = GFC^{\alpha}POP^{\beta}CMP^{\gamma 1}EMP^{\gamma 2}EC^{\delta 1}OILC^{\delta 2}COALC^{\delta 3}NGC^{\delta 4}EFP^{\theta 1}CFP^{\theta 2}GDP^{\rho 1}AVA^{\rho 2}FDI^{\rho 3} \quad (8)$$

Equation (8) indicates the mechanism through which monetary policy, fiscal policy and energy consumption, along with control variables, impact CO2 emissions.

4. Data and Methodology

4.1 Data

In this study, historical data ranging from 1974 to 2020 is used to investigate the influence of fiscal policy, monetary policy and energy consumption on carbon dioxide (CO2) emissions in the context of pre- and post-liberalization. The data (1974-2020) is decomposed into two parts: the 1974 to 1994 years indicating the pre-liberalization period and the 1995 to 2020 years representing the post-liberalization period. CO2 emissions in kilotons, for measuring environmental degradation in Pakistan, is used as an outcome variable. Government expenditures, in constant local currency units, are used as a fiscal policy variable (FP), which is decomposed into contractionary fiscal policy (CFP), or a negative change in FP and expansionary fiscal policy (EFP), or a positive change in FP. Broad money as a percentage of GDP is served as a proxy for the monetary policy variable (MP), which is decomposed into contractionary monetary policy (CMP), or a negative change in MP and expansionary monetary policy (EMP), or a positive change in MP. Energy consumption is disaggregated into four components: electricity consumption (EC) in gigawatt-hours, oil consumption (OILC) in tons, coal consumption (COALC) in thousand metric tons and natural gas consumption (NGC) in million cubic feet. Population (POP) in numbers is taken as a proxy for labor and gross fixed capital formation (GFC) in constant local currency units is used as a proxy of capital. Furthermore, some other control variables, including gross domestic product (GDP) and agricultural value added (AV), are served in constant local currency units and foreign direct investment (FDI) is used in current US dollars. Data regarding EC, OILC, COALC and NGC is taken from an economic survey of Pakistan. Whereas data concerning all other variables is based on world development indicators (WDI).

4.2 Multicollinearity Diagnostics

Multicollinearity is defined as a strong linear relationship between two or more independent variables. The presence of multicollinearity significantly affects the estimation by inflating the standard errors of predicted coefficients; thereby they become unstable and statistically insignificant (Paetzold, 1992). Therefore, it is crucial to detect the multicollinearity before employing any econometric technique. One way to diagnose the multicollinearity is to analyze the simple pairwise correlations between the explanatory variables. The simple coefficient of correlation, r_{ij} determines the strength and direction of the linear association between two regressors. It is calculated utilizing the following formula:

$$r_{ij} = \frac{\sum(X_i - \bar{X}_i)(X_j - \bar{X}_j)}{\sqrt{\sum(X_i - \bar{X}_i)^2 \sum(X_j - \bar{X}_j)^2}} \tag{9}$$

Where X_i and X_j are explanatory variables, $r_{ij} = 1$ for all i = j, it is equal to the coefficient of correlation between X_i and X_j when $i \neq j$. According to this criterion, multicollinearity is severe if the simple correlation coefficient, in absolute value, exceeds 0.80 (Willis and Perlack, 1978). If there are more than two explanatory variables in a regression model, simple pairwise correlations between the predictors are informative but should not be the only criterion used to identify whether or not multicollinearity is a problem. Other diagnostic metrics, such as the VIF and the CI, should also be used and reported (Tu et al., 2005). The VIF is another metric for detecting the severity of multicollinearity between the explanatory variables. There is one VIF for each independent variable in an equation. It reveals the extent of increase in the variance of an estimated coefficient that arises due to multicollinearity. It is calculated using the following formula:

$$VIF_i = \frac{1}{1 - R_i^2} \tag{10}$$

Where R_i^2 is the proportion of the variation for each auxiliary regression when each predictor is regressed on the remaining predictors. According to this method, it is considered that no multicollinearity is if the VIF value is 1, whereas if the VIF value is more than 5 or 10, then it will be considered as severe multicollinearity (Kyriazos and Poga, 2023). The CI is another measure used for multicollinearity diagnostics. It is calculated by the following formula:

$$CI_i = \sqrt{\frac{\kappa_{max}}{\kappa_i}} \tag{11}$$

Where κ_{max} indicates the maximum eigenvalue and κ_i represents the minimum eigenvalue. According to this metric, there is no multicollinearity when all condition indices are unity. There is no exact rule for how large a CI must be to identify a multicollinearity problem. An informal rule of thumb for identifying multicollinearity is that, if the CI value is 15, multicollinearity is severe (Midi et al., 2010).

4.3 Methodology

The paramount objective of this study is to determine the influence of fiscal policy, monetary policy and energy consumption on carbon dioxide (CO2) emissions in the context of pre- and post-liberalization in Pakistan. The influence of several macroeconomic policies on CO2 emissions was examined in previous empirical studies. We have modified the Cobb-Douglas production-related pollution function following earlier studies for different countries. Our econometric model can be presented as follows:

$$lnCO2 = \alpha + \beta_1\, lnGDP + \beta_2\, lnAVA + \beta_3\, lnEC + \beta_4\, lnOILC + \beta_5\, lnPOP + \beta_6\, lnGFC + \beta_7\, lnFP$$

$$+\beta_8\, lnFDI + \beta_9\, lnCOALC + \beta_{10}\, lnNGC + \beta_{11} lnMP + \varepsilon \qquad (12)$$

In equation (12), ln shows the natural log, CO2 symbolizes the carbon dioxide emissions, GDP stands for gross domestic product, AVA denotes the agricultural value added, EC is the electricity consumption, OILC is the oil consumption, POP is the size of the population, GFC is the capital formation, FP is the fiscal policy variable, FDI is the foreign direct investment, COALC is the coal consumption, NGC is the natural gas consumption, MP is the monetary policy variable and ε is the random error term. We can modify equation (12) by decomposing the fiscal policy variable (lnFP) and the monetary policy variable (lnMP) into two variables, with the first one indicating a decrease in fiscal and monetary policy variables and the second one showing an increase in fiscal and monetary policy variables. We disaggregate these variables as follows:

$$lnCFP_t = \sum_{n=1}^{t} \Delta lnFP_t^- = \sum_{n=1}^{t} \min(\Delta lnFP_t^-, 0) \qquad (13)$$

$$lnEFP_t = \sum_{n=1}^{t} \Delta lnFP_t^+ = \sum_{n=1}^{t} \max(\Delta lnFP_t^+, 0) \qquad (14)$$

$$lnCMP_t = \sum_{n=1}^{t} \Delta lnMP_t^- = \sum_{n=1}^{t} \min(\Delta lnMP_t^-, 0) \qquad (15)$$

$$lnEMP_t = \sum_{n=1}^{t} \Delta lnMP_t^+ = \sum_{n=1}^{t} \max(\Delta lnMP_t^+, 0) \qquad (16)$$

Where lnCFP represents the contractionary fiscal policy, lnEFP denotes the expansionary fiscal policy, lnCMP indicates the contractionary monetary policy and lnEMP signifies the expansionary monetary policy. After incorporating these lnCFP, lnEFP, lnCMP and lnEMP policies into equation (12), we can get the following equation:

$$lnCO2 = \alpha + \beta_1\, lnGDP + \beta_2\, lnAVA + \beta_3\, lnEC + \beta_4\, lnOILC + \beta_5\, lnPOP + \beta_6\, lnGFC + \beta_{7EFP}\, lnEFP$$

$$\beta_{7CFP}\, lnCFP + \beta_8\, lnFDI + \beta_9\, lnCOALC + \beta_{10}\, lnNGC + \beta_{11EMP} lnEMP + \beta_{11CMP} lnCMP + \varepsilon \qquad (17)$$

Equation (17) can be used to investigate the impact of fiscal policy, monetary policy and energy consumption on the CO2 emissions. We will estimate equation (17) using correlated component regression (CCR) methodology, recently proposed by Magidson (2013). The CCR technique provides more reliable and stable predictions even when there is near multicollinearity in the regressors. One important feature of the CCR metric is that it is a scale-invariant technique, implying that it provides identical results whether predictions are based on standardized or unstandardized predictors. In contrast, traditional techniques such as PLS-R and penalized regression, including Ridge Regression, Lasso and Elastic Net are very sensitive to the scale of predictors and thereby produce various results based on predictor scaling applied. In the previous economic literature, the CCR methodology used by Bullock (2021) to find out the state-level impact of corn and soybean production on their total corn and soybean production in the United States. Naveed and Hina (2023) have applied this technique to examine the extent to which division-level wheat production affects total wheat production in the Punjab province of Pakistan. Similarly, Naveed et al. (2024) also used the same method to identify district-level cotton impact on total cotton production in Punjab, Pakistan. The CCR technique has also been used in this study to determine the influence of fiscal policy, monetary policy and energy consumption on CO2 emissions.

The general procedure of the CCR analytic approach is described as follows:
At this first stage, we will fit the regression equations utilizing OLS for each and every regressor separately. This is indicated as follows:

$$ln\hat{Y} = \hat{\gamma}_g^{(1)} + \hat{\lambda}_g^{(1)} lnX_g \quad (18)$$

In equation (18), ln indicates the natural logarithm, Y is the explained variable and Xg specifies regressors, where g = 1, 2, 3,…, P, and $\hat{\gamma}_g^{(1)}$ and $\hat{\lambda}_g^{(1)}$are the respective constant coefficient and regression coefficient for a specific explanatory variable g. The first component variable, lnS1 measures the effects of prime regressors, which have a direct effect on the explained variable. It is the weighted average of all 1-predictor effects, whereas the weights are regression coefficients obtained from equation (18). Its calculation is as follows:

$$lnS_1 = \frac{1}{P}\sum_{g=1}^{P} \hat{\lambda}_g^{(1)} lnX_g \quad (19)$$

The predictions for the explained variable lnY in the 1-component CCR model are generated by regressing a simple OLS of lnY on lnS1:

$$ln\hat{Y} = \hat{\alpha}^{(1)} + \hat{\beta}_1^{(1)} lnS_1 \quad (20)$$

The second correlated component variable, lnS_2, is derived by first estimating equation (21) for each predictor using simple OLS:

$$ln\hat{Y} = \hat{\gamma}_g^{(2)} + \hat{\lambda}_{1,g}^{(2)} lnS_1 + \hat{\lambda}_g^{(2)} lnX_g \quad (21)$$

The second component, lnS_2, then becomes the weighted mean of all the 2-predictor impacts and is calculated as follows:

$$lnS_2 = \frac{1}{P}\sum_{g=1}^{P} \hat{\lambda}_g^{(2)} lnX_g \quad (22)$$

Regressing a basic OLS of lnY on lnS_1 and lnS_2 produces the predictions for the outcome variable Y (in the form of a natural logarithm) in the 2-component CCR model:

$$ln\hat{Y} = \hat{\alpha}^{(2)} + \hat{\beta}_1^{(2)} lnS_1 + \hat{\beta}_2^{(2)} lnS_2 \quad (23)$$

Accordingly, the aforementioned procedure for obtaining the correlated component variables can be followed as far as the optimal number of component variables is reached. Usually, for any set of K (K< P) correlated component variables, we will fit the following regression equation for each regressor utilizing the OLS:

$$ln\hat{Y} = \hat{\gamma}_g^{(K)} + \hat{\lambda}_{1,g}^{(K)} lnS_1 + \hat{\lambda}_{2,g}^{(K)} lnS_2 + \cdots + \hat{\lambda}_{K-1,g}^{(K)} lnS_{K-1} + \hat{\lambda}_g^{(K)} lnX_g \quad (24)$$

Finally, the last component variable, lnS_k, is then found using equation (25):

$$lnS_k = \frac{1}{P}\sum_{g=1}^{P} \hat{\lambda}_g^{(k)} lnX_g \quad (25)$$

Regressing a simple OLS of lnY on lnS_1, lnS_2…, lnSk yields the predictions for the explained variable Y (in the form of a natural logarithm) in the k-component CCR model:

$$ln\hat{Y} = \hat{\alpha}^{(K)} + \hat{\beta}_1^{(K)} lnS_1 + \hat{\beta}_2^{(K)} lnS_2 + \cdots + \hat{\beta}_k^{(K)} lnS_k \quad (26)$$

Inserting equations (19), (22), and (25) into equation (26) yields equation (27):

$$ln\hat{Y} = \hat{\alpha}^{(K)} + \hat{\beta}_1^{(K)}\left(\frac{1}{P}\sum_{g=1}^{P}\hat{\lambda}_g^{(1)} lnX_g\right) + \hat{\beta}_2^{(K)}\left(\frac{1}{P}\sum_{g=1}^{P}\hat{\lambda}_g^{(2)} lnX_g\right) + \cdots + \hat{\beta}_k^{(K)}\left(\frac{1}{P}\sum_{g=1}^{P}\hat{\lambda}_g^{(k)} lnX_g\right) \quad (27)$$

Rearranging and simplifying equation (27) gives equation (28):

$$ln\hat{Y} = \hat{\alpha}^{(K)} + \sum_{k=1}^{k}\hat{\beta}_k^{(K)}\left(\frac{1}{P}\sum_{g=1}^{P}\hat{\lambda}_g^{(k)} lnX_g\right) \quad (28)$$

$$ln\hat{Y} = \hat{\alpha}^{(K)} + \sum_{g=1}^{P}\hat{\beta}_g\, lnX_g \quad (29)$$

Thus, the estimated regression coefficient $\hat{\beta}_g$ is a weighted mean of the loadings. The regression coefficients of the K-component CCR model, as expressed in equation (26), serve as weights:

$$\hat{\beta}_g = \frac{1}{P}\sum_{k=1}^{P}\hat{\beta}_k^{K}\hat{\lambda}_g^{(k)} \quad (30)$$

Substituting lnCO2 for lnY in equation (29) and including all relevant predictors produces an equation identical to equation (17), which we want to estimate.

Equation (30) provides the estimates of unstandardized coefficients, whereas the standard errors of estimated coefficients can be estimated using the following formula:

$$SE(\hat{\beta}_g) = \frac{1}{P}\sqrt{\sum_{k=1}^{K}\left(SE(\hat{\beta}_k^{K})\right)^2(\hat{\lambda}_g^{k})^2} \quad (31)$$

Where $\hat{\lambda}_g^{k}$ indicates the loadings on all correlated component variables and $SE(\hat{\beta}_k^{K})$ denotes the coefficient's standard error for the K-component CCR model, as represented in equation (26). Standardized regression coefficients in absolute values are employed to assess the relative significance of each explanatory variable with respect to CO2 emissions. These coefficients are produced by applying the following formula:

$$\hat{\beta}_g^{*} = \left(\frac{\hat{\sigma}_g}{\hat{\sigma}_y}\right) \times \hat{\beta}_g \quad (32)$$

Where $\hat{\beta}_g^{*}$ and $\hat{\beta}_g$ respectively denote the standardized and unstandardized coefficients of each of the regressors with g equaling 1, 2, 3…, P. Furthermore, $\hat{\sigma}_g$ and $\hat{\sigma}_y$ measure the dispersion as a standard deviation for each regressor and explained variable, respectively, with g indicating 1, 2, 3…,P. Standardized coefficients represent which explanatory variable has a higher influence on the explained variable. More specifically, the standardized regression coefficient calculates the marginal influence of each explanatory variable on the dependent variable. The relative contribution of each explanatory variable to CO2 emissions is calculated using standardized regression coefficients as an absolute value, which is then expressed as a percentage of their absolute sum. Explanatory variables with a greater contribution to CO2 emissions indicate that a one-standard deviation change in their value has a greater influence on the explained variable (CO2 emissions).

5. Results and Discussions

Table 1 provides a description of variables, whereas Table 2 displays the findings of summary statistics. The average carbon dioxide (CO2) emission, in natural log, of Pakistan studied between 1974 and 2020 was 11.27 kilotons, with 9.97 kilotons and 12.20 kilotons as the smallest and highest values, respectively. The extent to which the CO2 emission deviates from the average, measured by the standard deviation, is 0.67 kilotons. Further, the descriptive statistics indicate that the mean for all variables except lnCOALC is less than the median, implying a negative skewness as evidenced by negative skewness coefficients of lnCO2, lnGDP, lnAVA, lnEC, lnOILC, lnPOP, lnGFC, lnFP, lnFDI, lnNGC and lnMP. The kurtosis values for all variables other than lnMP are less than 3, indicating that all these variables exhibit the platykurtic distribution. However, the kurtosis value for lnMP is 3.41, thereby its distribution is leptokurtic.

Simple pairwise correlations between the predictors are obtained using equation (9), and the results are provided in Table 3. Correlation can be used to check the likelihood of multicollinearity between the predictors. All the pairwise correlations between the explanatory variables are positive, as indicated in Table 3, implying that all regressors are positively associated with each other. Since all the pairwise correlation coefficients, except those of lnMP with all other variables, are greater than 0.80. Therefore, the correlation matrix suggests the existence of severe multicollinearity among regressors.

Table 1: Description of Variables

Name of Variables	Abbreviation	Measurement Unit	Source
CO2 Emission	lnCO2	Kilotons	WDI & Our World in Data
Gross Domestic Product	lnGDP	Constant Local Currency Unit	WDI
Agricultural Value Added	lnAVA	Constant Local Currency Unit	WDI
Electricity Consumption	lnEC	Gigawatt-Hour	Economic Survey of Pakistan
Oil/Petroleum Consumption	lnOILC	Tons	Economic Survey of Pakistan
Total Population	lnPOP	Numbers	WDI
Gross Fixed Capital Formation	lnGFC	Constant Local Currency Unit	WDI
General Government Final Consumption Expenditure	lnFP	Constant Local Currency Unit	WDI
Foreign Direct Investment	lnFDI	Current US Dollars	WDI
Coal Consumption	lnCOALC	Thousand metric ton	Economic Survey of Pakistan
Natural Gas Consumption	lnNGC	Million Cubic Feet	Economic Survey of Pakistan
Broad Money	lnMP	Percentage of GDP	WDI

Source: Author's Compilation

Table 4 reports the results of the VIF and the CI. The VIF and the CI are calculated using equations (10) and (11), respectively. Both methods diagnose the likelihood of multicollinearity among the predictors. Since all the VIF values excluding lnMP exceed 10, indicating severe multicollinearity between the explanatory variables. In addition to the VIF, the condition index also supports the likelihood of severe multicollinearity among the predictors. As the highest value of the condition index is 160.39, which is greater than 15, therefore the multicollinearity is severe. The presence of strong multicollinearity among predictors leads to unstable and statistically insignificant coefficient estimates (Paetzold, 1992). Therefore, we need to apply an econometric technique suitable for collinear datasets. The CCR approach is particularly well suited for collinear and sparse datasets, as it provides more reliable and stable predictions even when regressors are severely multicollinear. (Magidson, 2013).

Table 2: Summary Statistics

Variables	Mean	Median	Max	Min	S.D	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
lnCO2	11.27	11.40	12.20	9.97	0.67	-0.48	2.06	3.58	0.17	47
lnGDP	30.29	30.34	31.25	29.11	0.64	-0.27	1.95	2.71	0.26	47
lnAVA	29.04	29.12	29.73	28.23	0.48	-0.25	1.70	3.77	0.15	47
lnEC	10.45	10.67	11.63	8.74	0.86	-0.58	2.14	4.05	0.13	47
lnOILC	16.21	16.50	17.06	14.90	0.65	-0.72	2.14	5.48	0.06	47
lnPOP	18.72	18.77	19.24	18.01	0.38	-0.33	1.85	3.49	0.17	47
lnGFC	28.49	28.53	29.34	27.39	0.52	-0.37	2.23	2.26	0.32	47
lnFP	28.02	28.03	29.04	26.75	0.64	-0.32	2.14	2.27	0.32	47
lnFDI	19.74	20.04	22.44	15.20	1.76	-0.60	2.67	3.07	0.22	47
lnCOALC	8.27	8.15	10.14	6.97	0.80	0.32	2.40	1.54	0.46	47
lnNGC	13.27	13.30	14.19	11.81	0.73	-0.38	1.91	3.48	0.18	47
lnMP	3.75	3.77	4.00	3.36	0.14	-0.76	3.41	4.91	0.09	47

Source: Author's calculations

Given the likelihood of severe multicollinearity, we will apply the CCR approach to investigate the influence of fiscal policy, monetary policy and energy consumption on carbon dioxide (CO2) emissions in Pakistan.

Magidson (2010) showed that CCR effectively performs with 2, 3 or 4 correlated component variables. Following Magidson (2010), this study has used only 2 component variables, S1 and S2, omitting the third and fourth components due to having insignificant loadings, which also fail to significantly improve the prediction for the dependent variable. Moreover, we have retained all explanatory variables to assess the effect of fiscal and monetary policies, as well as energy consumption, on CO2 emissions.

Table 3: Correlation Matrix

Predictors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
lnGDP (1)	1										
lnAVA (2)	0.995	1									
lnEC (3)	0.992	0.987	1								
lnOILC (4)	0.960	0.961	0.979	1							
lnPOP (5)	0.997	0.998	0.992	0.967	1						
lnGFC (6)	0.988	0.976	0.987	0.954	0.981	1					
lnFP (7)	0.988	0.972	0.984	0.945	0.979	0.987	1				
lnFDI (8)	0.939	0.933	0.951	0.922	0.939	0.956	0.931	1			
lnCOALC (9)	0.965	0.953	0.945	0.874	0.951	0.959	0.959	0.902	1		
lnNGC (10)	0.990	0.989	0.987	0.954	0.993	0.982	0.973	0.956	0.949	1	
lnMP (11)	0.502	0.463	0.475	0.403	0.461	0.549	0.553	0.503	0.547	0.450	1

Source: Author's calculations

Table 5 shows the findings of unstandardized and standardized regression coefficients for the CCR model with two component variables before and after liberalization. Upper part of this table indicates the estimation of the component variables prior to the liberalization. The estimated results indicate that both correlated component variables S1 and S2 are significant at the 95% confidence level. The first component variable, S1, measures the prime variable's (direct) effect, accounting for 33.87 percent of the total contribution as an absolute sum of standardized regression coefficients. In contrast, the second correlated component, S2, represents the suppressor variable's (indirect) effect, accounting for 66.13 percent. Lower part of Table 5 reports the estimated results of the CCR model during the post-liberalization period. Both the correlated components in this period are also significant at the 99% confidence level. In this period, prime variables have a dominant effect, capturing 80.69 percent, whereas suppressor variables have contributed only 19.31 percent. It is worth noting that the impact of suppressor variables was stronger during the pre-liberalization period, while the prime variables were dominant during the post-liberalization period.

Table 4: Variance Inflation Factor and Condition Index

Predictors	Variance Inflation Factor (VIF)			Condition Index (C.I)	
	R_i^2	$1 - R_i^2$	VIF	Eigenvalues	C.I
lnGDP	0.9992	0.0008	1254.7051	9.9553	1.0000
lnAVA	0.9971	0.0029	341.7635	0.7647	3.6081
lnEC	0.9969	0.0031	327.4394	0.1225	9.0132
lnOILC	0.9910	0.0090	111.1235	0.0887	10.5963
lnPOP	0.9994	0.0006	1612.9032	0.0310	17.9235
lnGFC	0.9940	0.0060	166.8892	0.0191	22.8554
lnFP	0.9893	0.0107	93.6067	0.0097	32.0859
lnFDI	0.9535	0.0465	21.4947	0.0052	43.6960
lnCOALC	0.9774	0.0226	44.2791	0.0022	67.7482
lnNGC	0.9960	0.0040	252.2704	0.0013	88.3634
lnMP	0.6724	0.3276	3.0523	0.0004	160.3880

Source: Author's calculations

Unstandardized and standardized regression coefficients of all explanatory variables during the pre-liberalization period are obtained from equations (30) and (32), respectively and the estimated results are summarized in Table 6. Empirical findings authenticate that gross domestic product has a positive and statistically significant impact on CO2 emissions. More precisely, a 1.0 percent increase (decrease) in gross domestic product results in a 0.2232 percent increase (decrease) in CO2 emissions, holding all other predictors constant. This suggests that a rise in GDP leads to an increase in pollution. Our findings regarding agricultural value added indicate that agricultural value added has a positive but insignificant influence on CO2 emissions. According to results, a 1.0 percent increase (decrease) in agricultural value added would result in a 0.0366 percent increase (decrease) in CO2 emissions, implying a degradation of environmental quality.

Electricity consumption and oil consumption both have a positive significant effect on CO2 emissions, implying that a 1.0 percent increase (decrease) in electricity and oil consumption, respectively, leads to a 0.1248 percent and 0.0778 percent increase (decrease) in CO2 emissions. Population and GFC also have a positive significant influence on CO2 emissions. Our estimates authenticate that a 1.0 percent acceleration (deceleration) in population would cause a 0.4301 percent acceleration (deceleration) in CO2 emissions. On the other hand, a 0.0383 percent rise (fall) in CO2 emissions is associated with a 1.0 percent rise (fall) in gross fixed capital formation.

Table 5: Unstandardized and Standardized Regression Coefficients of the Correlated Component Regression Model with K = 2

Correlated Component	Un-Standardized Coefficients	Std.Error	T-Statistic	P-Value	Standardized Coefficients	Contribution (%)
CCR Model Before Liberalization						
lnS1	0.3642**	0.1450	2.5127	0.0217	0.3386	33.8675
lnS2	3.7890*	0.7722	4.9065	0.0001	0.6612	66.1325
CCR Model After Liberalization						
lnS1	0.9602*	0.0668	14.3664	0.0000	0.8141	80.6877
lnS2	3.4430*	1.0012	3.4388	0.0022	0.1949	19.3135

Source: Author's calculations. *, ** and *** respectively indicate that the coefficients are significant at 99%, 95% and 90% confidence level.

If the effects of fiscal policy FP are evaluated, asymmetric results are found in terms of contractionary and expansionary fiscal policy. CFP corresponds to contractionary fiscal policy, indicating declines in government expenditure, whereas EFP corresponds to expansionary fiscal policy, denoting an increase in government expenditure. Our results regarding contractionary fiscal policy indicate that a 1.0 percent contraction in government expenditure under contractionary CFP leads to a 0.05 percent reduction in CO2 emissions. However, its impact is statistically insignificant. On the other hand, expansionary fiscal policy has a significant positive influence on CO2 emissions, implying that a 1.0 percent increase in government expenditure under expansionary fiscal policy would result in a 0.0452 percent increase in CO2 emissions. It indicates that expansionary fiscal policy enhances CO2 emissions, which become the cause of environmental degradation in the country. Results concerning fiscal policy indicate that expansionary fiscal policy has a greater influence, in terms of standardized regression coefficients, on CO2 emissions than contractionary fiscal policy during the pre-liberalization period. Our results regarding foreign direct investment indicate that it has a positive but insignificant influence on CO2 emissions. COALC and NGC are positively and significantly associated with CO2 emissions. A 1.0 percent increase (decrease) in coal and natural gas consumption, respectively, would result in a 0.0834 percent and 0.0979 percent increase (decrease) in CO2 emissions.

Table 6: CCR Model Regression Results (Pre-Liberalization Period)

Predictors	Un-Standardized Coefficients	Std. Error	T-Statistic	Standardized Coefficients	Contribution (%)
lnGDP	0.2232*	0.0409	5.4547	0.1883	18.6971
lnAVA	0.0366	0.0205	1.7867	0.0199	1.9796
lnEC	0.1248*	0.0228	5.4779	0.1725	17.1298
lnOILC	0.0778*	0.0147	5.2814	0.0848	8.4184
lnPOP	0.4301*	0.0793	5.4228	0.2093	20.7785
lnGFC	0.0383**	0.0140	2.7264	0.0301	2.9877
lnCFP	-0.0500	0.0565	-0.8833	-0.0067	0.6605
lnEFP	0.0452*	0.0108	4.1672	0.0496	4.9259
lnFDI	0.0051	0.0037	1.3871	0.0146	1.4521

lnCOALC	0.0834*	0.0164	5.0735	0.0730	7.2449
lnNGC	0.0979*	0.0181	5.4012	0.0958	9.5103
lnCMP	-0.1278*	0.0342	-3.7378	-0.0423	4.1992
lnEMP	0.0469	0.0254	1.8451	0.0203	2.0159
Constant	-10.5011*	0.7486	-14.0274		

Source: Author's calculations. *, ** and *** respectively indicate that the coefficients are significant at 99%, 95% and 90% confidence level.

Evaluating the monetary policy (MP) effects, we find asymmetric results in terms of coefficients of CMP and EMP policy. CMP corresponds to contraction in the monetary policy, denoting a decline in money supply. On the other hand, EMP corresponds to expansion in the monetary policy, representing an increase in the money supply. Our empirical results indicate that a 1.0 percent decrease in the money supply under contractionary CMP policy would result in a 0.1278 percent decrease in CO2 emissions. Conversely, a rise in the money supply under expansionary EMP policy results in a 0.0469 percent rise in CO2 emissions following a 1.0 percent raise in the money supply. However, the CMP policy has a statistically significant influence, while the EMP policy has an insignificant influence on CO2 emissions. Based on the monetary policy effects, the CMP policy reduces environmental pollution in the country, while the EMP policy increases environmental pollution in the economy. The monetary policy results indicate that the CMP policy had a stronger impact on CO2 emissions than the EMP policy during the pre-liberalization period. Our findings regarding fiscal and monetary policies conclude that EFP and CMP policies are effective in changing CO2 emissions, while CFP and EMP policies are ineffective in changing carbon emissions in Pakistan during the pre-liberalization period.

Unstandardized and standardized regression coefficients of all explanatory variables during the post-liberalization period are obtained from equations (30) and (32), respectively and the estimated results are summarized in Table 7. Empirical findings point out that gross domestic product has a positive and significant effect on CO2 emissions. Specifically, a 1.0 percent acceleration (deceleration) in gross domestic product leads to a 0.1781 percent acceleration (deceleration) in CO2 emissions while holding all other regressors constant. This suggests that a rise (fall) in GDP would lead to an increase (decrease) in pollution in the country during the post-liberalization period. Agricultural value added positively and significantly affects CO2 emissions. A 1.0 percent change in agricultural value added results in a 0.1366 percent change in CO2 emissions, implying a degradation of environmental quality. Electricity and oil consumption both statistically and significantly impact CO2 emissions, implying that a 1.0 percent change in electricity and oil consumption, respectively, leads to a 0.1262 percent and 0.1208 percent change in CO2 emissions, ceteris paribus. Population and GFC also have a positive significant influence on CO2 emissions. Particularly, a 1.0 percent change in population would lead to a 0.0974 percent change in CO2 emissions. On the other hand, a 0.1229 percent acceleration (deceleration) in CO2 emissions is associated with a 1.0 percent acceleration (deceleration) in gross fixed capital formation, ceteris paribus.

Table 7: CCR Model Regression Results (Post-Liberalization Period)

Predictors	Un-Standardized Coefficients	Std. Error	T-Statistic	Standardized Coefficients	Contribution (%)
lnGDP	0.1781*	0.0337	5.2790	0.2063	19.5457
lnAVA	0.1366*	0.0137	9.9978	0.1034	9.8002
lnEC	0.1262*	0.0195	6.4586	0.1515	14.3560
lnOILC	0.1208*	0.0112	10.7632	0.0742	7.0257
lnPOP	0.0974*	0.0104	9.3349	0.0590	5.5853
lnGFC	0.1229*	0.0155	7.9120	0.1200	11.3704
lnCFP	-0.0615***	0.0298	-2.0666	-0.0262	2.4828
lnEFP	0.0724*	0.0092	7.8544	0.1242	11.7643
lnFDI	0.0175*	0.0012	14.2507	0.0511	4.8420
lnCOALC	0.0323*	0.0022	14.7102	0.0696	6.5945
lnNGC	-0.0023	0.0177	-0.1302	-0.0028	0.2650
lnCMP	-0.0264***	0.0131	-2.0112	-0.0230	2.1830
lnEMP	0.0404*	0.0087	4.6442	0.0442	4.1851
Constant	-7.4505*	1.0572	-7.0477		

Source: Author's calculations. *, ** and *** respectively indicate that the coefficients are significant at 99%, 95% and 90%

confidence level.

Evaluating the effects of fiscal policy (FP), asymmetric results are found in terms of CFP and EFP policies. The CFP and EFP policies have respectively, a negative significant and positive significant effect on CO2 emissions. The CFP policy results represent that a 1.0 percent reduction in government expenditure causes a 0.0615 percent decrease in CO2 emissions, implying the CFP policy improves the environmental quality. Conversely, a 1.0 percent reduction in government expenditure under the EFP policy leads to a 0.0724 percent reduction in CO2 emissions. This shows that EFP policy enhances CO2 emissions and mitigates environmental quality. Fiscal policy results authenticate that expansionary fiscal policy has a stronger influence on CO2 emissions as compared to contractionary fiscal policy during the post-liberalization period.

Foreign direct investment and coal consumption have a positive and statistically significant influence on CO2 emissions during the post-liberalization period, implying that CO2 emissions increase (decrease) 0.0175 percent and 0.0323 percent in response to a respective 1.0 percent increase (decrease) in foreign direct investment and coal consumption. However, natural gas consumption has an inverse but statistically insignificant influence on CO2 emissions.

Evaluating the effects of monetary policy (MP), similar to fiscal policy, we find asymmetric results in terms of coefficients of CMP and EMP policy. Both the CMP and EMP policies have a significant effect on CO2 emissions during the post-liberalization period, with the former being significant at the 10% level and the latter at the 1% significance level. The CMP policy results show that a 1.0 percent decrease in money supply, under contractionary monetary policy, represents a 0.0264 percent fall in CO2 emissions, indicating that the CMP policy improves environmental quality. Conversely, a 1.0 percent increase in money supply under expansionary monetary policy leads to a 0.0404 percent rise in CO2 emissions. This indicates that expansionary monetary policy increases CO2 emissions, which increases environmental pollution. Monetary policy results authenticate that expansionary monetary policy has a stronger effect on CO2 emissions than contractionary monetary policy during the post-liberalization period. Our findings regarding fiscal and monetary policies conclude that expansionary and contractionary fiscal and monetary policies are effective in changing carbon emissions during the post-liberalization period.

Each predictor's relative contribution to CO2 emissions is determined using the absolute values of standardized regression coefficients, expressed as a percentage of their absolute sum. Estimated results regarding each predictor's relative contribution are summarized in the last column of Tables 6 and 7. During the pre-liberalization period, among the included predictors, population had the largest contribution at 20.78 percent, followed by gross domestic product (18.70%), electricity consumption (17.13%), natural gas consumption (9.51%), oil consumption (8.42%), coal consumption (7.24%), expansionary fiscal policy (4.93%), contractionary monetary policy (4.20%), and gross fixed capital formation (2.99%). During the post-liberalization, gross domestic product had the largest contribution at 19.55 percent on average, followed by electricity consumption (14.36%), expansionary fiscal policy (11.76%), gross fixed capital formation (11.37%), agricultural value added (9.80%), oil consumption (7.03%), coal consumption (6.59%), population (5.59%), foreign direct investment (4.84%), expansionary monetary policy (4.19%), contractionary fiscal policy (2.48%), and contractionary monetary policy (2.18%).

Table 8: Diagnostic Tests of the Correlated Component Regression Model

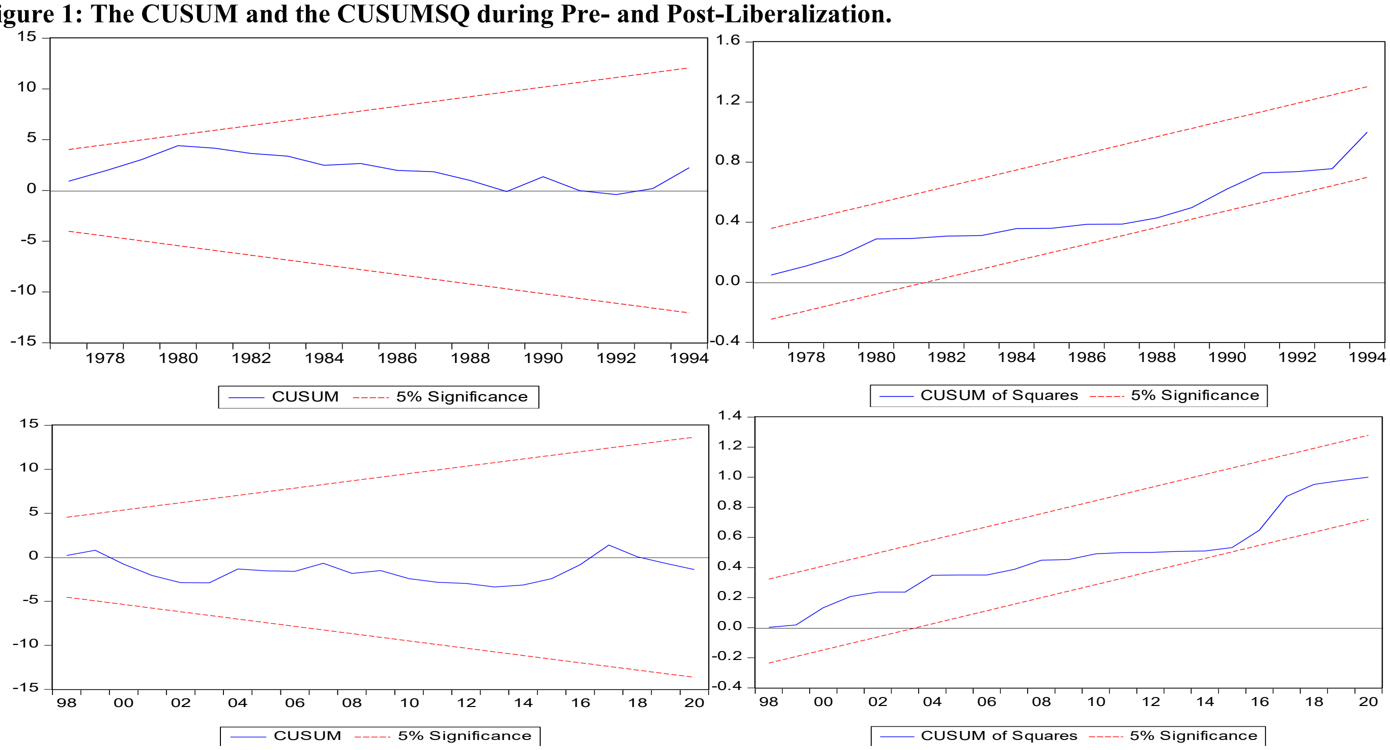
Name of Test	Critical value	Calculated value of Test Statistic	P-value
Before Liberalization			
Normality Test (Jarque Bera)	$\chi^2_{0.05(2)} = 5.99$	1.48	0.48
Serial Correlation LM Test	$\chi^2_{0.05(1)} = 3.84$	0.23	0.63
ARCH Test	$\chi^2_{0.05(1)} = 3.84$	`0.10	0.76
Ramsey Reset Test	$F_{0.05(1,17)} = 4.45$	0.18	0.67
After Liberalization			
Normality Test (Jarque Bera)	$\chi^2_{0.02(2)} = 7.82$	6.81	0.03

Serial Correlation LM Test	$\chi^2_{0.05(1)} = 3.84$	0.23	0.63
ARCH Test	$\chi^2_{0.05(1)} = 3.84$	0.01	0.93
Ramsey Reset Test	$F_{0.05(1,22)} = 4.30$	0.11	0.74

Source: Author's calculations.

Table 8 reports the results of the different diagnostic tests that are used to assess the validity and stability of the CCR model during pre- and post-liberalization. The primary goals of these tests were to evaluate the non-normality of residuals, autocorrelation, heteroscedasticity and stability of the estimated parameters. The normality assumption of residuals was assessed using the Jarque-Bera test. Estimated results of this test indicate that residuals of the CCR model follow the normal distribution, implying that the normality assumption is satisfied during the pre- and post-liberalization period. The serial correlation LM test is also conducted to detect autocorrelation. Our findings concerning the LM test indicate the absence of autocorrelation, which means the one-time period's disturbances are uncorrelated with disturbances in another time period. The ARCH test is used to examine the heteroscedasticity, which shows the unequal variance of residuals. Estimated results of the ARCH test show that the equal-variance assumption of disturbances is satisfied, implying the absence of heteroscedasticity during pre- and post-liberalization. The Ramsey Reset test was also employed to investigate the specification and possible misspecification of the CCR model. Estimated results regarding this test indicate that the CCR model is correctly specified, indicating that the selected predictors explain the sufficient variance in the explained variable during pre- and post-liberalization.

Figure 1: The CUSUM and the CUSUMSQ during Pre- and Post-Liberalization.



Source: Author's calculations

Moreover, the estimated parameter's stability of the CCR model was investigated considering the plots of cumulative sum (CUSUM) and squares cumulative sum (CUSUMSQ) of residuals. The plots of CUSUM and CUSUMSQ are shown in Figure 1. This figure shows that, at a 95% confidence level, the CUSUM and CUSUMSQ plots fall inside the red straight lines. Therefore, the parameters of the CCR model are structurally stable, implying that the CCR model is reliable and consistent during pre- and post-liberalization periods.

6. Conclusion and Policy Recommendations

The paramount aim of this study is to determine the influence of fiscal policy, monetary policy, and energy consumption on CO_2 emissions in Pakistan before and after liberalization, considering gross domestic product, agricultural value added, capital formation, population, and FDI as control variables. The historical timespan from 1974 to 2020 has been subdivided into two separate spans: the 1974 to 1994 years, indicating the pre-liberalization period and the 1995 to 2020 years, representing the post-liberalization period. During the pre- and post-liberalization periods, empirical findings have been determined employing the correlated component regression methodology. Our findings illustrate that both the contractionary fiscal and monetary policies have an inverse influence on CO2 emissions during the pre-liberalization, with the former being insignificant and the latter significant. In the pre-liberalization period, expansionary fiscal policy has a significant positive influence on carbon emissions, whereas expansionary monetary policy affects carbon emissions positively but insignificantly. In the post-liberalization period, both contractionary fiscal and monetary policies have a significant negative effect on CO2 emissions, while expansionary fiscal and monetary policies affect CO2 emissions significantly and positively. Our findings regarding fiscal and monetary policies conclude that only expansionary fiscal and contractionary monetary policies are effective, whereas contractionary fiscal and expansionary monetary policies are ineffective in changing CO2 emissions during the pre-liberalization period. Conversely, all the fiscal and monetary policies, expansionary as well as contractionary, are effective in changing CO2 emissions during the post-liberalization period. Electricity, oil, and coal consumption all have a significant positive influence on CO2 emissions during the pre- and post-liberalization periods, whereas the effect of natural gas consumption on carbon emissions is significant and positive only in the pre-liberalization. Moreover, the results indicate that the GDP, population, and gross fixed capital formation significantly increase the environmental pollution both in the pre- and post-liberalization periods. Agricultural value added and FDI also enhanced the environmental pollution, having a significant effect on CO2 emissions only in the post-liberalization.

During the pre-liberalization period, among the included predictors, population had the largest contribution at 20.78 percent on average, followed by gross domestic product (18.70%), electricity consumption (17.13%), natural gas consumption (9.51%), oil consumption (8.42%), coal consumption (7.24%), expansionary fiscal policy (4.93%), contractionary monetary policy (4.20%), and gross fixed capital formation (2.99%). During the post-liberalization period, gross domestic product had the largest contribution at 19.55 percent on average, followed by electricity consumption (14.36%), expansionary fiscal policy (11.76%), gross fixed capital formation (11.37%), agricultural value added (9.80%), oil consumption (7.03%), coal consumption (6.59%), population (5.59%), foreign direct investment (4.84%), expansionary monetary policy (4.19%), contractionary fiscal policy (2.48%), and contractionary monetary policy (2.18%). Validity and stability of the CCR model during the pre- and post-liberalization periods were checked using various diagnostic tests. The main objective of these tests was to test the non-normality of residuals, autocorrelation, heteroscedasticity, and parameter stability. Our estimated results illustrated that the CCR model satisfied all these diagnostic tests. Moreover, the parameter's stability of the CCR model was examined considering the plots of cumulative sum (CUSUM) and squares cumulative sum (CUSUMSQ) of residuals.

Based on our findings, the government should raise environment-related expenditures through expansionary fiscal and monetary policies to achieve fair and sustainable economies with low carbon emissions. The expansionary fiscal policy would be focused on green budgeting with special emphasis on environmental protection, targeting renewable energy, and promoting green infrastructure in manufacturing. Moreover, the government should implement such policies with objectives to change fossil fuel-based technologies to environmentally friendly energy activities, including thermal, wind, hydro, and solar-based energies. Conversely, when implementing an expansionary monetary policy, the monetary authority should provide feedback on financing measures to ensure that increased money in circulation leads to productive and environmentally friendly activities. Along with the development and implementation of green financial instruments such as green equity, green bonds, green loans and green insurance.

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