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Assessing the influence of fiscal and monetary policies on carbon dioxide emissions

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ABSTRACT

This paper examines the impact of fiscal and monetary policies on carbon dioxide emissions in Trinidad and Tobago, using data from 1970 to 2020. We use a fiscal policy index based on government revenue and expenditure, a monetary policy index based on interest rates and reserve requirement data, and a Non-linear Autoregressive Distributed Lag technique. Our results show that expansionary fiscal policy raises emissions, while contractionary fiscal policy reduces emissions. Intriguingly, expansionary monetary policy increases emissions, while contractionary monetary policy lowers them. These findings hold significance for fiscal and monetary policy-makers working on climate change mitigation strategies.

1. Introduction

Climate change is an urgent global concern, requiring immediate action to transform economies to a low-carbon future. The [Intergovernmental Panel on Climate Change \(2022\)](#) report warns that global warming is expected to reach 1.5°C between 2030 and 2050 and will continue upward if action is not taken to curb greenhouse gas emissions. Economists and scientists strongly agree that global warming and climate change severely threaten economic development outcomes, livelihoods, and human existence.

In many countries, fossil fuel consumption drives economic activities, which induces CO₂ emissions. In most hydrocarbon exporting economies, the problem of energy consumption from fossil fuel resources is more pronounced, given that hydrocarbon exports comprise a significant source of foreign earnings. For instance, in Trinidad and Tobago, the high level of per capita emissions stems from the industrialized nature of the economy. Trinidad and Tobago is a small, open economy that exports crude oil, liquefied natural gas, and petrochemicals. The country is also a key exporter of manufactured goods to the Caribbean. These activities translate to significant CO₂ emissions. Policy measures to curb CO₂ emissions are therefore crucial in the domestic context. On the one hand, fossil fuel resources drive domestic economic growth, which induces CO₂ emissions. However, on the other, the country needs to transition to low-carbon status to meet its commitments under international agreements.

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In light of the rise in emissions in many countries, researchers are increasingly probing the effects of various factors, with a particular focus on the effects of macroeconomic policies in the emissions-generating process. Fiscal and monetary policies, which are important drivers of aggregate demand, economic growth, income levels, and inflation management, have become the subject of growing interest in the context of climate change. However, few studies have investigated the effects of expansionary and contractionary fiscal and monetary policies on environmental emissions. The shortage of studies on the effects of these policies on emissions is even more glaring in countries where fossil fuel energy exports form a major component of public revenue and spending and where large swings in international energy prices drive economic conditions such as investment, consumption, output growth, and inflation. Exploring the influence of macroeconomic policies on environmental emissions may also reveal potential policy issues relating to achieving sustainable development since energy exporting-economies are faced with the need to decouple fossil fuels from their models of growth and development, which has become a requirement for competitiveness and sustainable economic growth.

Given the current research gap, the primary purpose of this paper is to empirically examine the effect of fiscal and monetary policies on CO₂ emissions in Trinidad and Tobago. We hypothesize that expansionary and contractionary fiscal and monetary policies have distinct and measurable effects on CO₂ emissions in Trinidad and Tobago. The remainder of the paper is structured as follows: [Section 2](#) discusses the literature on the effects of fiscal and monetary policy actions on CO₂ emissions. [Section 3](#) shares some stylized facts on Trinidad and Tobago's CO₂ emissions, energy consumption, and fiscal and monetary policy trends. [Section 4](#) discusses the methodology and data used to assess the impact of the policies on CO₂ emissions. [Section 5](#) discusses the results, and [Section 6](#) concludes with a few policy recommendations.

2. Literature review

Our literature review focuses on (i) the theoretical literature on the mechanisms linking the fiscal and monetary stance to emissions, and (ii) the empirical findings on the effects of these policies in various countries.

2.1. Theoretical literature

Several researchers have analyzed the effects of fiscal and monetary policies on CO₂ emissions using the Cobb-Douglas production function framework. [Sinai and Stokes \(1989\)](#) and [Benchimol \(2015\)](#) argued that real money balances constitute an important factor of production. Including a variable to reflect this factor input may produce a more complete production function specification. Therefore, the Cobb-Douglas production function, which incorporates real cash balances, can be represented in [Eq. \(2.1\)](#) as follows:

$$Y_t = AK_t^\alpha L_t^\beta M_t^\pi \quad (2.1)$$

where Y_t = final output, K_t = physical capital, and L_t = labor. The constant A represents total factor productivity, which reflects technological progress and other factors that affect overall production efficiency. The exponents α , β and π give the elasticities of final output with respect to capital, labor, and real cash balances, respectively. The inclusion of M_t reflects the assumption by several authors that real money balances held by firms constitute an important factor of production. Firms hold money balances to ensure they can purchase capital and meet daily expenses to ensure production occurs. Dividing through by L_t , [Eq. \(2.2\)](#) is derived as follows:

$$y_t = Ak_t^\alpha m_t^\pi \quad (2.2)$$

where $y_t = Y_t/L_t$, and $k_t = K_t/L_t$ and $m_t = M_t/L_t$. Many economists agree that production activities are mainly responsible for generating pollution emissions such as CO₂. We, therefore, derive the pollution function by substituting y_t with CO_{2epct} in [Eq. \(2.3\)](#):

$$CO_{2epct} = Ak_t^\alpha m_t^\pi \quad (2.3)$$

where CO_{2epct} represents CO₂ emissions per capita. In [Eq. \(2.3\)](#), the type of physical capital employed by firms can trigger industrial activities that threaten the environment. That is, physical capital employed in industrial activities can be of two types: eco-friendly and non-eco-friendly. Eco-friendly capital utilizes renewable energy sources, such as solar or nuclear, while non-eco-friendly capital requires non-renewable energy sources, such as fossil fuels. Thus, k_t can be disaggregated, as shown in [Eq. \(2.4\)](#) as follows:

$$k_t = k_R + k_N \quad (2.4)$$

According to the liquidity preference theory, the interest rate adjusts to balance money supply and demand. Also, the interest rate is one of the essential tools of monetary policy of a central bank. The central bank can vary the money supply in an economy by altering the interest rate. Monetary policy thus directly impacts the real cash balances firms hold. The adjusted production-based pollution function can be written as in [Eq. \(2.5\)](#)

$$CO_{2epct} = Ak_{t(R)}^\alpha k_{t(N)}^\beta I_t^\pi \quad (2.5)$$

where I_t is the policy instrument of the central bank. [Eq. \(2.5\)](#) thus shows that renewable energy capital goods (R), fossil fuel consumption capital goods (N), and the monetary policy are important factors in CO_{2epct} . We also replace k_t with renewable energy consumption and fossil fuel consumption, respectively ([Eq. \(2.6\)](#)).

$$CO_{2epct} = A[R]_t^\alpha [N]_t^\beta I_t^\pi \quad (2.6)$$

A central bank may pursue expansionary monetary policy or contractionary monetary policy depending on its policy objective at a given time. Monetary policy is designed to impact the money supply of the central bank. Money supply changes through expansionary or contractionary policy impact bank credit, investment spending, consumption spending, and inflation. According to [Qingquan et al. \(2020\)](#), expansionary monetary policy occurs when the central bank cuts its interest rate or reserve requirement to increase the money supply. Such a move will directly impact economic agents, particularly consumers and producers in the economy. Consumers will experience an improvement in purchasing power since they can borrow from commercial banks to finance the purchase of goods. Firms will also experience a reduction in borrowing costs for investment. An increase in consumers' purchasing power and a decline in borrowing costs will entice firms across various sectors of the economy to borrow to invest in plant and machinery. If the plant and equipment utilize fossil fuels directly or indirectly (from fossil-based power generation plants), this situation will increase CO_{2epct} .

In contrast, contractionary monetary policy describes a situation in which the central bank uses monetary policy instruments (the interest rate or reserve requirement) to reduce the money supply. Such a situation will also have direct impacts on economic agents. An interest rate increase will reduce consumers' borrowing and purchasing power. Firms in the industrial and manufacturing sectors will have less incentive to produce goods. Since these firms will also face increased financing costs for new capital investment projects, they will reduce their borrowing to purchase capital goods. Energy sector firms may also reduce their capital investments and output due to the increase in the cost of bank credit. This pattern of behavior by economic agents will lead to a reduction in CO_{2epct} .

Eq. (2.6) can be extended to integrate expansionary monetary policy and contractionary monetary policy by including two new variables: I_t^+ which are positive changes in I_t or contractionary monetary policy and I_t^- which include negative changes in I_t or expansionary monetary policy. These additional variables for monetary policy can be seen in Eq. (2.7) below:

$$CO_{2epct} = A[R]_t^\beta [N]_t^\beta I_t^{\pi^+} I_t^{\pi^-} \tag{2.7}$$

Fiscal policy may also contribute to changes in CO_{2epct} in an economy and can also be incorporated into the pollution production function. Fiscal policy involves the government changing its spending and revenue to influence aggregate demand and economic activities. Fiscal policy can also be categorized into either expansionary or contractionary. Expansionary fiscal policy is when the government increases expenditures, cuts taxes or combines both. Increasing expenditures or cutting taxes increases consumers' disposable incomes and spending power. Firms respond to the increase in consumer demand by increasing their output. The increase in output requires consumption of energy by manufacturing firms, which increases the production of CO_{2epct} . From an energy economy standpoint, a reduction in taxes for energy sector companies will also entice energy companies to increase the production of energy and increase their investment in plant and machinery. The production and refining of energy-related products increases CO_{2epct} in the economy. In contrast, contractionary fiscal policy refers to a situation where the government reduces spending, raises taxes, or combines both. These measures will reduce consumers' disposable incomes and aggregate demand in the economy. Firms, will also respond to the decrease in consumer demand by reducing their output of goods. In the case of fossil-based economies, energy firms will be less incentivized to produce energy-related goods, and reduce their investments in the energy sector, thus reducing energy consumption and CO_{2epct} emissions.

Eq. (2.7) can be modified to incorporate contractionary and expansionary fiscal policy by adding two variables: G_t^+ for an increase in spending or expansionary fiscal policy and G_t^- for a decrease in spending or contractionary fiscal policy. These inclusions are shown in Eq. (2.8).

$$CO_{2epct} = A[R]_t^\beta [N]_t^\beta I_t^{\pi^+} I_t^{\pi^-} G_t^+ G_t^- \tag{2.8}$$

Eq. (2.8) represents the mechanism by which monetary and fiscal policy impact CO_{2epct} emissions.

[Halkos and Paizanos \(2013\)](#) indicated that the impact of fiscal policy depends on the interaction of income-pollution and fiscal policy-economic growth relations. The economic literature has described various channels through which fiscal policy (or government spending) may impact economic growth. These channels are subject to interference by various factors, which could complicate the potential impacts of fiscal policy on economic growth. Some studies found that public expenditure may reduce economic growth by crowding out the private sector, increasing government inefficiencies, distorting tax systems and incentives, and intervening in free markets. Others found that government spending may positively affect economic growth due to positive externalities, providing a socially optimal level of growth and offsetting market failures. The EKC (Environmental Kuznets Curve) strand of literature has explored the income-pollution mechanism ([Grossman & Krueger, 1995](#)).

It is important to note that fiscal policy in countries can respond to natural disasters from CO₂ emissions. However, the extent and effectiveness of the response can vary across countries. There are several ways countries may respond to these disasters. These responses could include disaster relief, recovery funding and government disaster-related insurance protection. The response of fiscal policies to natural disasters is reflective of the endogeneity linkages between CO₂ emissions and fiscal policy.

Monetary policy actions, which are transmitted through complex channels, can also impact real output and inflation. The main channels through which monetary policy operates include the interest rate, credit, balance sheet, and asset price channels. However, monetary policy effectiveness often depends on the existence of various channels of monetary policy transmission. For instance, in some economies where capital markets (stock and bond markets) are underdeveloped, the interest rate channel may be less effective in influencing economic conditions and inflation. In such situations, monetary policy changes may be transmitted through the bank credit channel. In these countries, expansionary and contractionary monetary policy can alter economic agents' (firms and households) ability to borrow to finance consumption and investment activities, thus altering energy consumption patterns, aggregate demand, production activities, and inflation, and by extension, impact income per capita and CO₂ emissions.

2.2. Empirical literature on the effects of fiscal and monetary policies on CO₂ emissions

Prior studies have found mixed results about the effects of expansionary and contractionary shocks to fiscal policy instruments, and policy stance on CO₂ emissions (see Appendix Table A1). For instance, [Yilanci and Pata \(2021\)](#) investigated the Group of Seven (G7) countries using data for 1875-2016 and found that public spending helped reduce emissions. [Katircioglu and Katircioglu \(2018\)](#) investigated the case of Turkey using data from 1960 to 2013 and found that increased public spending (or an expansionary shock to fiscal policy instruments) led to reduced emissions. On the other hand, in an earlier study, [Bernauer and Koubi \(2006\)](#) found that an increase in government spending is associated with more emissions, with the only exception being expenditure on public goods. [Halkos and Paizanos \(2013\)](#) found that government expenditure has a direct negative impact on sulphur dioxide emissions but has an insignificant effect on CO₂ emissions. Their study further revealed an indirect negative relationship between government expenditure and sulphur dioxide emissions in low-income countries, but the effect becomes positive as income increases. [Yuelen et al. \(2019\)](#) explored the impact of public revenue and spending in China from 1980 to 2016 and found that expansionary fiscal policy increases CO₂ emissions. However, the expansionary policy had a favorable short-term impact on emissions. [Mahmood et al. \(2022\)](#) found that government expenditure has a positive and scale effect on territory-based CO₂ and consumption-based CO₂ in Gulf Cooperation Council (GCC) economies through increasing CO₂ emissions.

[Halkos and Paizanos \(2016\)](#) examined the effects of fiscal spending on CO₂ emissions using quarterly data for the United States from 1973 to 2013. The study found that the effects of fiscal policy depended on the pollution source, fiscal policy scenario, and the composition of government spending under consideration. [Lopez et al. \(2011\)](#) argued that reallocating government spending towards social and public goods reduces sulphur dioxide emissions. The authors identified four channels through which fiscal spending could impact emissions: scale, composition, techniques, and income effects. The scale effect refers to the pressures induced on the environment because of increasing economic growth. The composition effect refers to changes in the composition of economic activity and sectors that impact emissions differently. The technique effect refers to the influence of changes in labor efficiency and education on environmental quality. The income effect refers to the increasing need for a better quality environment due to the high-income status of the population. Their study utilized data from 38 countries over the period 1986 to 1999.

Prior studies have led to mixed conclusions about the effects of expansionary and contractionary monetary actions on emissions (see Appendix Table A1). For instance, [Qingquan et al. \(2020\)](#) found that expansionary monetary policy intensifies CO₂ emissions; but contractionary monetary policy appeared to contract emissions in 14 Asian economies. [Isiksal et al. \(2019\)](#) found a negative relationship between monetary policy (the real interest rate) and CO₂ emissions in Turkey. The paper further revealed that the impact of the monetary policy variable was supported by the energy consumption channel in Turkey. However, [Muhafidin \(2020\)](#) found a positive relationship in Indonesia. In [Pradeep \(2021\)](#), interest rates were similarly identified to possess a significant positive relationship with CO₂ emissions in India.

Further, [Chishti et al. \(2021\)](#) found that expansionary (contractionary) monetary policies ameliorate (deteriorate) CO₂ emissions in Brazil, Russia, India and China (BRIC). In the case of Pakistan, [Ullah et al. \(2021\)](#) found that a negative and positive shock to monetary policy instruments enhances CO₂ emissions in the short run. In contrast, a positive shock decreases CO₂ emissions in the long run. A regional study on the Association of Southeast Asian Nations (ASEAN) countries showed that contractionary monetary policy reduces CO₂ emissions, while expansionary monetary policy enhances CO₂ emissions in the long run ([Mughal et al., 2021](#)).

There is a growing body of empirical research investigating the effects of fiscal and monetary policies on CO₂ emissions. The literature review also reveals that there is increasing recognition that fiscal and monetary policies, via their impacts on the level and structure of economic activities in a country, can have adverse emissions consequences. However, there remains a research gap in the countries still needs to investigate this important issue, especially given that CO₂ emissions are linked to the global issue of climate change. A very limited number of available studies have investigated the effects of expansionary and contractionary fiscal and monetary policies on emissions. Further, in economies that are heavily reliant on fossil fuels for public finances and economic growth and development, understanding the complexities of expansionary and contractionary fiscal and monetary policies on emissions is crucial, given the potential spillover effects. Prior literature supports our hypothesis that expansionary and contractionary fiscal and monetary policies can influence CO₂ emissions in Trinidad and Tobago. Therefore, empirical testing is warranted.

3. Stylized facts

Although Trinidad and Tobago's contribution to global CO₂ emissions has been considered low in absolute terms, the country is a significant contributor to global emissions per capita. In 2018, Trinidad and Tobago held the second-highest position in the world in terms of CO₂ emissions per capita. ([Fig. 1](#))¹. Per capita emissions experienced an upsurge since the late 1990s and peaked in 2010. Even though there was a decline after 2010, emission levels remained elevated. The high level of per capita emissions stems from the industrialized hydrocarbon-based nature of the economy. The country's economic activity is dominated by the commercialization of its natural gas and crude oil resources. The country also exports manufactured goods such as food and beverages and construction materials such as cement to the Caribbean. These activities make the economy a significant contributor to global CO₂ emissions.

From [Fig. 1](#) there appears to be a direct association between CO₂ emissions per capita, energy consumption per capita, and real GDP per capita. The decline in CO₂ emissions and energy consumption in 2009 and 2014 was primarily because of the global financial crisis

¹ Data source: Our World in Data based on Global Carbon Project 2021.

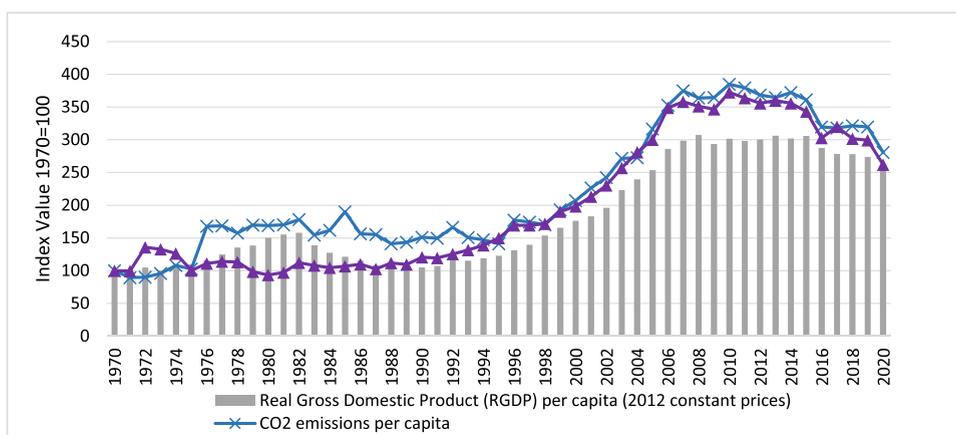


Fig. 1. Trends in per capita carbon dioxide emissions, real gross domestic product and energy consumption.

Note: Data used refers to production-based carbon dioxide emissions or territorial emissions. Data were converted into index values to aid comparison. Source: Global Carbon Project, Our World in Data and Central Statistical Office.

of 2008 and the freefall in energy commodity prices², respectively. Additionally, the downward movement in CO₂ emissions and energy consumption from 2019 onwards was primarily a result of the coronavirus disease 2019, which affected economic activity. This pattern suggests that as per capita income increases in Trinidad and Tobago, so do CO₂ emissions, indicating that the country's economic development is not yet fully aligned with green technology.

Fig. 2 provides a sectoral decomposition of CO₂ emissions for Trinidad and Tobago for 2019³. Power generation for use in energy production plants (such as liquefied natural gas and refined energy products) and industrial and manufacturing activities require burning fossil fuels, which contribute significantly to CO₂ emissions. The latest data show that electricity and heat accounts for 39.3 percent of total emissions. Fig. 2 also shows that fugitive emissions (20.9 percent) and industrial (including manufacturing) (20.6 percent) are the three sectors that are significant contributors to emissions in 2019. These emissions are generated either through burning fossil fuels or as a by-product of production activities.

Fig. 3 illustrates the evolution of government fiscal policy and CO₂ emissions in Trinidad and Tobago, utilizing data spanning 1970 to 2020. It is noteworthy that periods of elevated expenditure per capita frequently coincide with augmented revenue (revenue per capita), and conversely, a reduction in government spending often corresponds with diminished revenue, thereby reinforcing the notion of fiscal policy's procyclical nature (Cotton et al., 2013). A parallel pattern is also observable in CO₂ emissions per capita, mirroring government expenditure and revenue fluctuations. This synchrony raises the possibility of a substantive connection between government fiscal policy and CO₂ emissions. However, it is essential to exercise caution in ascribing a direct cause-and-effect relationship between fiscal policy and emissions. Numerous intricate factors interplay within an economic ecosystem, and this analysis does not, for instance, account for the potential mediating role of gross domestic product. The intricate relationships between fiscal policy, economic growth and emissions, warrant further investigation since the impact of fiscal policy on emissions depends on the influence of fiscal policy on economic growth. Government spending might stimulate economic activity, including energy-intensive industries, potentially contributing to CO₂ emissions. Additionally, government revenue, often tied to the energy sector, may carry out its emissions footprint. Consequently, Fig. 3 underscores a possible link between fiscal policy and emissions, which requires deeper analysis.

A less definitive narrative emerges from Fig. 4, which delineates the interplay between monetary policy and CO₂ emissions. Fig. 4 does not reveal a discernible and direct association between monetary policy variables and CO₂ emissions in Trinidad and Tobago. Fig. 4 shows some co-movement between monetary policy variables, such as the 3-month Treasury bill rate and bank discount rate⁴. Also, a similar co-movement pattern exists between the reserve requirement ratio and the bank discount rate. Conversely, the reserve requirement ratio exhibits lower co-movement with the 3-month Treasury bill rate. These patterns, however, do not provide a clear basis for establishing a direct connection between monetary policy and CO₂ emissions.

It is imperative to acknowledge the complexity of monetary policy's potential influence on emissions. Fig. 4 does not preclude the existence of a relationship but necessitates further investigation. Many studies have already affirmed a significant impact of interest rates on credit availability, investment, consumption, and aggregate demand, all of which can and have repercussions for CO₂ emissions. Therefore, while Fig. 4 does not corroborate a direct causal link between monetary policy and CO₂ emissions in Trinidad

² The freefall in energy commodity prices resulted in the Government's deliberate effort to consolidate aggregate expenditure. There was a 7.0 percent cut in expenditure across government ministries.

³ The authors were unable to obtain sectoral data for CO₂ emissions. However, Fig. 2 shows greenhouse gas emissions for 2019 converted to carbon dioxide equivalent.

⁴ The bank discount rate was utilized as the policy interest rate instead of the repo rate due to the unavailability of data before 2002. The bank rate is set at 200 basis points above the repo rate.

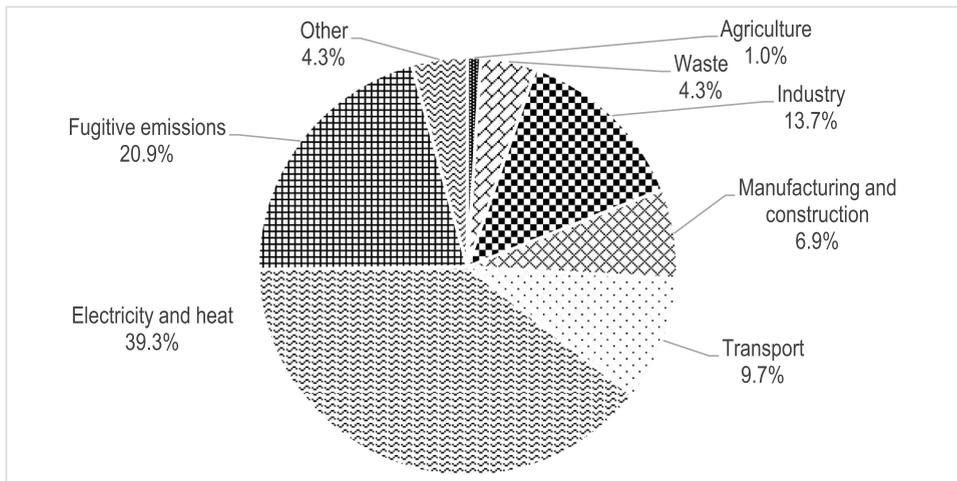


Fig. 2. Share of total carbon dioxide emissions by sector in Trinidad and Tobago in 2019.
 Note: Data used to calculate the sectoral shares is in metric tonnes of carbon dioxide-equivalents. The other category includes: aviation and shipping, other fuel combustion, land use, and buildings. Source: Our World in Data.

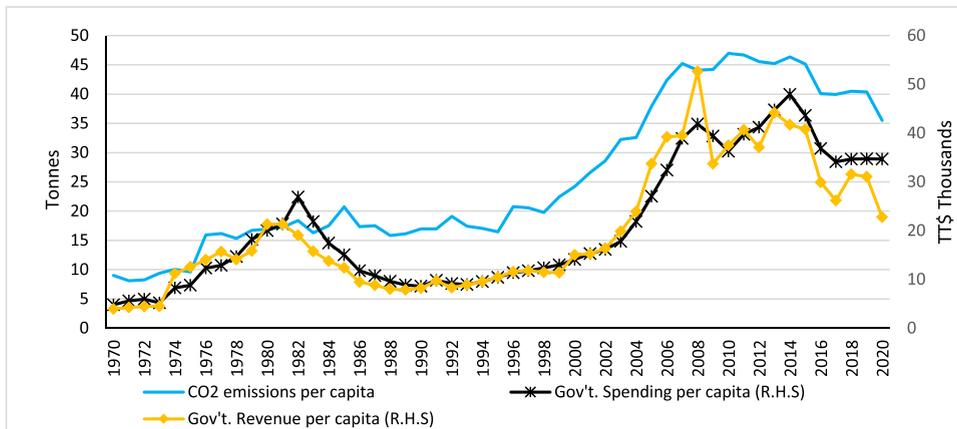


Fig. 3. Trends in public expenditure, revenue and CO₂ emissions.
 Sources: Our World in Data and Central Bank of Trinidad and Tobago (Handbook of Economic Statistics)

and Tobago, it underscores the need to clarify the intricate channels through which monetary policy might affect emissions.

4. Methodology and data

4.1. Econometric methodology

Our methodology for analyzing the effects of fiscal and monetary policy on emissions is the non-linear autoregressive distributed lag (NARDL) model. This model allows for the inclusion of both I(0) and I(1) variables but is unsuitable for variables with higher orders of integration. It provides information about both the short-run dynamics and long-run equilibrium in an error correction specification. An advantage of this model is that it corrects for weak endogeneity of non-stationary variables⁵. However, the model is suitable when a single cointegrating vector is found.

⁵ Applying the appropriate number of lags to the NARDL will address autocorrelation and endogeneity problems. Pesaran and Shin (1999) maintain that including and ARDL with the appropriate number of lags will address autocorrelation and endogeneity problems. It is difficult to ascertain that the relationship under investigation is in fact endogenous. Higher emissions and their consequences in terms of environmental degradation and climate-related natural disasters can have material impacts on the fiscal stance and the functioning of monetary policy. However, in the Trinidad and Tobago context, there is limited information to support that the fiscal and/or monetary authorities may be responding to higher emissions.

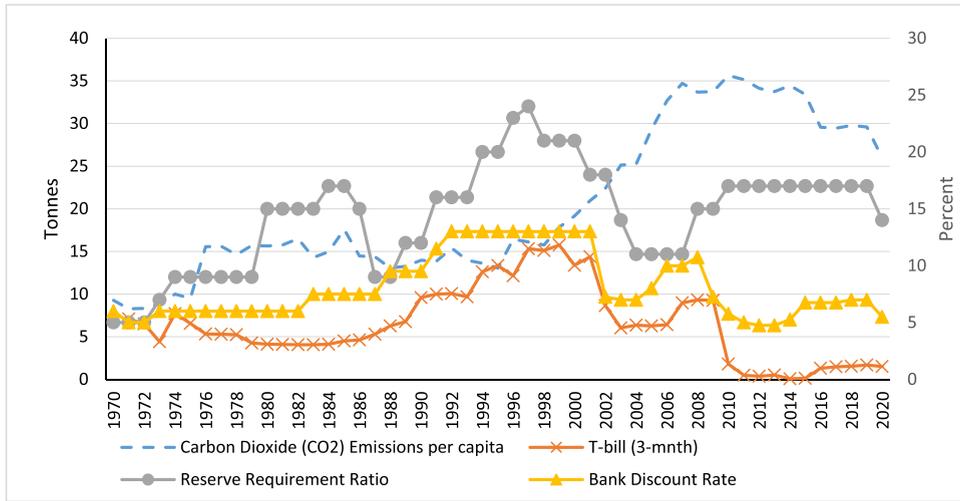


Fig. 4. Trends in the bank discount rate, reserve requirement, 3-month Treasury bill rate and CO2 emissions. Sources: Our World in Data and Central Bank of Trinidad and Tobago

Empirical studies have only recently begun exploring the impact of various macroeconomic policies on CO₂ emissions. Based on prior studies for other countries, we augment a Cobb-Douglas production-based pollution function. The empirical model is in Eq. (4.1) as follows:

$$LCO_{2e}PC_t = \delta_0 + \delta_1 LECPC_t + \delta_2 LCIN_t + \delta_3 LFPI_t + \delta_4 MPI_t + \delta_5 LIMC_t + \epsilon_t \tag{4.1}$$

where t represents the year and L logarithm. $LCO_{2e}PC_t$ denotes CO₂ emissions per capita, $LECPC_t$ is fossil fuel consumption per capita, $LCIN_t$ is carbon intensity⁶, $LFPI_t$ is the fiscal policy index (a measure of fiscal policy), MPI_t is the monetary policy index (a measure of monetary policy), and $LIMC_t$ is a measure of import capacity. Finally, ϵ_t is an error term. We divide the quantity variables by population to control for the effects of population growth on CO₂ emissions.

The next phase of the model is to incorporate short- and long-run effects into Eq. (4.1). We follow Pesaran et al. (2001) ARDL error correction and cointegration framework to incorporate these effects in Eq. (4.2).

$$\begin{aligned} \Delta LCO_{2e}PC_t = & \delta_0 + \sum_{i=1}^n \gamma_i \Delta LCO_{2e}PC_{t-i} + \sum_{i=0}^n \theta_{1i} \Delta LCIN_{t-i} + \sum_{i=0}^n \theta_{2i} \Delta LECPC_{t-i} + \sum_{i=0}^n \theta_{3i} \Delta LFPI_{t-i} + \sum_{i=0}^n \theta_{4i} \Delta MPI_{t-i} \\ & + \sum_{i=0}^n \theta_{5i} \Delta LIMC_{t-i} + \delta_1 LCO_{2e}PC_{t-1} + \delta_2 LECPC_{t-1} + \delta_3 LCIN_{t-1} + \delta_4 LFPI_{t-1} + \delta_5 MPI_{t-1} + \delta_6 LIMC_{t-1} + \epsilon_{t-1} \end{aligned} \tag{4.2}$$

The short-run impacts are revealed as “first-differenced” variables, and long-run impacts are yielded by the estimates of $\delta_2 - \delta_6$ normalized on δ_1 in Eq. (4.2). Indeed, for long-run estimates to be valid, cointegration among the variables must be established. Narayan (2005) endorses using the F-statistics to find a joint significance of the linear model and has presented a different set of tabulated critical values that are valid for small samples. A key assumption of the ARDL is that model variables have different integrating properties, i.e., I (0) or I (1), and even a mixture of both. However, none of the variables should be I (2).

The fundamental hypothesis in Eq. (4.1) or Eq. (4.2) is that fiscal and monetary policies have symmetric/linear effects on the environment regarding CO₂ emissions. CO₂ emissions are assumed to have the same elasticity for positive and negative shocks to fiscal and monetary policies. However, the symmetry assumption can be counterfactual, especially in studies such as this one, which examine the impact of monetary and fiscal policy on CO₂ emissions. It is possible that CO₂ emissions may respond differently to monetary and fiscal policy expansions and contractions⁷. This insight will be necessary for analyzing the impact of monetary and fiscal policies on CO₂ emissions. We modify Eq. (4.2) to detect possible asymmetric effects of monetary and fiscal policy on CO₂ emissions in the short and long run. Our specification follows the Shin et al. (2014) asymmetric error correction modeling approach. In this approach, we decompose fiscal policy ($LFPI_t$) and monetary policy (MPI_t) fluctuations into two time series variables, one signifying increases in fiscal and monetary policies and the other signifying decreases in monetary and fiscal policy⁸. We accomplish this using the partial sums approach as follows:

⁶ Carbon intensity is computed as the ratio of total energy consumption to gross domestic product multiplied by the ratio of total CO₂ emissions to gross domestic product.

⁷ The symmetry assumption can lead to incorrect inferences and policy conclusions, leading to ineffective policy prescription.

⁸ Granger et al. (2002) state that if two time series positive and negative components are cointegrated, they have hidden cointegration and linear cointegration is a particular case of this hidden cointegration which is a simple case of nonlinear cointegration.

$$LFPI_t^+ = \sum_{n=1}^t \Delta LFPI_t^+ = \sum_{n=1}^t \max(\Delta LFPI_t^+, 0) \tag{4.3}$$

$$LFPI_t^- = \sum_{n=1}^t \Delta LFPI_t^- = \sum_{n=1}^t \min(\Delta LFPI_t^-, 0) \tag{4.4}$$

$$MPI_t^+ = \sum_{n=1}^t \Delta MPI_t^+ = \sum_{n=1}^t \max(\Delta MPI_t^+, 0) \tag{4.5}$$

$$MPI_t^- = \sum_{n=1}^t \Delta MPI_t^- = \sum_{n=1}^t \min(\Delta MPI_t^-, 0) \tag{4.6}$$

In Eq. (4.3) to Eq. (4.6), $LFPI_t^+$ and MPI_t^- are the time series variables which capture the partial sum expansionary fiscal and monetary policies. Similarly, $LFPI_t^-$ and MPI_t^+ capture the partial sum of the contractionary fiscal and monetary policies. For the asymmetric or NARDL model, we replace the variables for fiscal and monetary policies in Eq. (4.2) with $LFPI_t^+ / LFPI_t^-$ and MPI_t^+ / MPI_t^- to obtain the following specification in Eq. (4.7):

$$\begin{aligned} \Delta LCO_{2e}PC_t = & \delta_0 + \sum_{i=1}^n \gamma_i \Delta LCO_{2e}PC_{t-i} + \sum_{i=0}^n \theta_{1i} \Delta LCIN_{t-i} + \sum_{i=0}^n \theta_{2i} \Delta LECPC_{t-i} + \sum_{i=0}^n \theta_{3i} \Delta LFPI_{t-i}^+ + \sum_{i=0}^n \theta_{4i} \Delta LFPI_{t-i}^- \\ & + \sum_{i=0}^n \theta_{5i} \Delta MPI_{t-i}^+ + \sum_{i=0}^n \theta_{6i} \Delta MPI_{t-i}^- + \sum_{i=0}^n \theta_{7i} \Delta LIMC_{t-i} + \delta_1 LCO_{2e}PC_{t-1} + \delta_2 LCIN_{t-1} + \delta_3 LECPC_{t-1} + \delta_4 LFPI_{t-1}^+ + \delta_5 LFPI_{t-1}^- \\ & + \delta_6 MPI_{t-1}^+ + \delta_7 MPI_{t-1}^- + \delta_8 LIMC_{t-1} + \epsilon_{t-1} \end{aligned} \tag{4.7}$$

Eq. (4.7) permits asymmetric testing in several ways. For instance, different estimates and lag structures of $LFPI_t^+ / LFPI_t^-$ and MPI_t^+ / MPI_t^- can shed light on the short-term asymmetry of the $CO_{2e}PC_t$ variable for the fiscal and monetary shocks. Also, the differences in the estimates of $LFPI_t^+ / LFPI_t^-$ and MPI_t^+ / MPI_t^- can notify us about the sign and size of the impact due to the partial sums. The Wald test can also be used to formally confirm the presence of short-run asymmetries by rejecting the null hypotheses $H_0 : \sum_{i=0}^q \theta_{3i} = \sum_{i=0}^q \theta_{4i}$ and $H_0 : \sum_{i=0}^q \theta_{5i} = \sum_{i=0}^q \theta_{6i}$. Finally, the long-run asymmetries of fiscal and monetary policies can be confirmed if the null hypotheses $H_0 : \frac{\delta_4}{\delta_1} = \frac{\delta_5}{\delta_1}$ and $H_0 : \frac{\delta_7}{\delta_1} = \frac{\delta_8}{\delta_1}$ are nullified in favor of a disparity.

Asymmetric dynamic multipliers can capture the impact of fiscal and monetary expansions and contractions on CO_2 emissions. We can use the following formulas (see Eqs. (4.8) to (4.11)) to compute the asymmetric dynamic multipliers:

$$m_h^+ = \sum_{j=0}^h \frac{\partial LCO_{2e}PC_{t+j}}{\partial LFPI_t^+} \tag{4.8}$$

$$m_h^+ = \sum_{j=0}^h \frac{\partial LCO_{2e}PC_{t+j}}{\partial MPI_t^+} \tag{4.9}$$

$$m_h^- = \sum_{j=0}^h \frac{\partial LCO_{2e}PC_{t+j}}{\partial LFPI_t^-} \tag{4.10}$$

$$m_h^- = \sum_{j=0}^h \frac{\partial LCO_{2e}PC_{t+j}}{\partial MPI_t^-} \tag{4.11}$$

By construction, when $h \rightarrow \infty$, $m_h^+ \rightarrow L_{LFPI^+}$, $m_h^- \rightarrow L_{LFPI^-}$, $m_h^+ \rightarrow L_{MPI^+}$ and $m_h^- \rightarrow L_{MPI^-}$. These multipliers could capture the cumulative effects of expansionary and contractionary policy on CO_2 emissions from an initial equilibrium to the new equilibrium, as shown by Shin et al. (2014).

4.2. Data description

The NARDL model is estimated by employing annual time series data from 1970 to 2020. The data were obtained from various sources.

The data on total CO_2 emissions, fossil fuel consumption, and carbon intensity of energy consumption⁹ were sourced from Our World in Data (Global Carbon Project)¹⁰. Carbon dioxide emissions per capita was obtained by dividing total CO_2 emissions by the total

⁹ The carbon intensity of energy consumption is the ratio of CO_2 emissions to total fossil fuel energy consumption.

¹⁰ See for further details: <https://ourworldindata.org/co2-emissions>.

population. Similarly, we obtained fossil fuel energy consumption per capita by utilizing annual population data. The data for the total population was obtained from the Central Statistical Office (CSO). Further, the definitions and the unit of measurement of CO₂ emissions and fossil fuel energy consumption can be obtained from Our World in Data. Import capacity, calculated by dividing total exports by total imports, was obtained from trade data from the Central Bank of Trinidad and Tobago. Government revenue and expenditure data were sourced from the Ministry of Finance and converted into per capita terms by dividing them by the total population. Also, government revenue and expenditure data were converted into 2015 constant prices using the core inflation rate obtained from the CSO and the Central Bank of Trinidad and Tobago. All data were taken in their logarithmic form (except for the interest rates and reserve requirement).

4.2.1. Fiscal policy index

A fiscal policy index was constructed using the method of Principal Component Analysis (PCA) to capture the fiscal policy stance efficiently. The data for government revenue (GREVPC) and government expenditure (GSPC) were used to construct this index via the PCA method¹¹. The degree of correlation between them must be determined before applying the PCA. Appendix Table A2 shows the correlation coefficients for these policy variables, which reveal a high degree of inter-correlation. Finally, the PCA weights were employed to construct a fiscal policy index.

The number of principal components (PCs) generated equals the number of variables used to construct the index, which means two PCs will be generated in this case. The first component accounts for the maximum variance, and the succeeding components account for smaller proportions. The variance accounted for a given component is expressed in eigenvalues. The sum of all the eigenvalues equals the number of variables or PCs generated. Table 1 shows the PCs and their respective eigenvalues. Under the eigenvalue-one criterion (also known as the Kaiser Criterion), only PCs with an eigenvalue of more than one have to be retained and interpreted. Table 1 also shows that only PC1 needs to be retained from the two PCs, which explains about 80.0 percent of the total variance. The eigenvector or the weights of different variables in PC1, as shown in Table 1, are multiplied by the time series of the respective variables¹². These weighted data are then added to make a new time series. This variable is converted into an index by taking the first value of the series as the base value.

4.2.2. Monetary policy index

Similarly, we construct a monetary policy index via PCA. Data for the bank discount rate, the 3-month Treasury bill rate, and the reserve requirement ratio are used to construct this index. Appendix Table A2 shows the correlation coefficients for the three policy variables having a reasonably high degree of inter-correlation, especially between the Treasury bill and the bank rate. However, these variables and the reserve requirement showed a relatively lower correlation. Table 2 shows the PCA results, where each PC generated has a specific weighted composition for the three variables. Table 2 shows that out of the three PCs, only PC1 needs to be retained, which explains about 72.0 percent of the total variance. The eigenvector or the weights of different variables in PC1, as shown in Table 2, are multiplied by the time series of the respective variables^{13,14}. These individually weighted data are then added to make a new time series index. The final variables used in our model are summarized in Table 3.

The descriptive statistics of the model variables are provided in Appendix Table A3. The table shows the mean, median, maximum, minimum, skewness, kurtosis, and Jarque-Bera test results for each data series. The Jarque-Bera test statistic is significant in some variables, meaning some variables are not normally distributed. Further, the correlation results (Appendix Table A2) indicate a strong positive correlation between the CO₂ePC and ECPC, GDPPC, FPI and IMC, but a weak negative correlation between CO₂ emissions and the bank rate and Treasury bill rate, and a weak positive correlation between the reserve requirement ratio. We also conducted unit root (Appendix B), non-linearity, and multicollinearity tests to determine the appropriateness of the model specification (Appendix C). The bounds test was also performed to determine the existence of cointegration (Appendix D).

5. Results

5.1. Short-run and long-run estimates

Overall, the empirical findings reveal that the stance of fiscal and monetary policies exert notable influences on CO₂ emissions in

¹¹ In Trinidad and Tobago, fiscal policy has mainly been procyclical over the years, whereby changes in public spending are positively associated with public revenue. Expansionary changes to public spending instruments often coincide with increasing revenues. Also, contractionary changes in public spending often occur when public revenue declines. Researchers usually advocate for the use of the change in the overall fiscal balance as a measure of the fiscal stance. However, in the context of our assessment of the expansionary and contractionary effects of fiscal policy on CO₂ emissions in Trinidad and Tobago, the use of the fiscal balance may mask the size of revenues generated and spending in the economy, which can influence the level of emissions. Therefore, our study looks at changes in revenue and spending as a measure of the fiscal stance. Also, in an effort to be consistent with the literature, we attempted to measure and include the cyclically adjusted fiscal balance in our fiscal policy index to provide a more comprehensive picture of the fiscal stance. However, data for one-off revenue and expenditures are unavailable over the length of our dataset.

¹² The weights were derived by dividing each component (0.707 and 0.707) by the sum of the components.

¹³ The same method was applied as in footnote 12.

¹⁴ Unlike the fiscal policy, we did not convert the weighted data into index values for econometric modeling since the data is expressed in percentages.

Table 1

Results of Principal Components Analysis for the government spending and revenue variables.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.608356	1.216712	0.8042	1.608356	0.8042
2	0.391644	—	0.1958	2.000000	1.0000
Eigenvectors					
Variable				Principal Component 1	Principal Component 2
Government Spending Per Capita				0.707107	-0.707107
Government Revenue Per Capita				0.707107	0.707107

Source: Eviews 9 output based on the authors' calculation.

Table 2

Results of Principal Components Analysis for the reserve requirement, bank discount rate, and Treasury bill rate variables.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.153752	1.384598	0.7179	2.153752	0.7179
2	0.769154	0.692061	0.2564	2.922907	0.9743
3	0.077093	—	0.0257	3.000000	1.0000
Eigenvectors					
Variable			Principal Component 1	Principal Component 2	Principal Component 3
Reserve Requirement			0.445234	0.859492	0.251079
Bank Rate			0.662564	-0.127618	-0.738053
3-month Treasury Bill rate			0.602308	-0.494962	0.626289

Source: Eviews 9 output based on authors' calculation.

Table 3

Variables description.

Variables	Abbreviation	Measurement	Source	Expected relationship with CO ₂ ePC
CO ₂ per capita	CO ₂ ePC	Metric tons/Total Population	Our World in Data	
Fossil Fuel Energy Consumption per capita	ECPC	Total hour Kilowatt /Population	Our World in Data	Positive
Carbon Intensity economic activity.	CIN	Total Fossil Energy Consumption (KWh)/Total GDP x Total CO ₂ Emissions/Total Fossil Energy Consumption (KWh)	Our World in Data	Positive
Fiscal Policy Index	FPI	Created using Principal Component Analysis of Government Spending per capita and Government Revenue per Capita	Ministry of Finance of Trinidad and Tobago	Positive or Negative
Monetary Policy Index	MPI	Created using Principal Component Analysis of the Bank Discount Rate 3-Month Treasury Rate Primary Reserve Requirement	Central Bank of Trinidad and Tobago	Positive or Negative
Import capacity	IMC	Total Exports/Total Imports	Central Bank of Trinidad and Tobago	Positive

Note: 1 Gross domestic product (GDP) is measured in 2017 international dollar and Purchasing Power Parity-adjusted. Gross domestic product data for 2019 and 2020 were estimated based on Central Statistical Office data.

Source: Authors' construction.

Trinidad and Tobago, with their varying effects in both the short and long run, shedding light on the complex interplay between these policies and CO₂ emissions. In Model 1, we used weights for the fiscal and monetary policy indices derived from PCA. The PCA provided an objective basis for assigning weights to the variables. In Model 1, the weights assigned to the bank discount rate, Treasury bill rate, and reserve requirement were 38.3 percent, 34.6 percent, and 27.1 percent, respectively. In Model 2 and Model 3, the weights for the bank discount rate and Treasury bill rate were increased to 50.0 percent, and the reserve requirement ratio was reduced to zero. This weighting allows us to explore the effects of indirect or market-based monetary policy tools on CO₂ emissions. In Model 3, we increased the weighting of the bank discount rate further to 75.0 percent. However, we assigned small weights to the Treasury bill rate (12.5 percent) and the reserve requirement (12.5 percent). The reason for the high weight assigned to the bank discount rate is that in Trinidad and Tobago, the bank discount rate is the proxy for the Repo rate, which is the primary monetary policy tool of the Central Bank of Trinidad and Tobago. Open market operations are used to manage excess liquidity conditions in the banking sector. However, given that the local capital market is in developmental stage, the full transmission of short-term interest rates (such as short-term Treasury bill rates) to long-term bond rates is delayed. The Central Bank currently employs the reserve requirement ratio (for

commercial banks), but the ratio is adjusted less frequently than the policy interest rate. In Model 4, we reverted to the PCA-assigned weights, but we added a dummy variable to reflect the pre- and post-global financial crisis of 2008 in our model to assess its influence on policies and emissions. The dummy variable is defined as zero for the years 1970 to 2008 and 1 from 2009 to 2020.

The results of the various diagnostic tests and the estimated short-run and long-run elasticity coefficients for the four NARDL models are presented in [Table 4](#). The diagnostic test results show that the error terms of the specification of the NARDL models are normally distributed, and the residuals are free from serial correlation and heteroscedasticity. Parameter stability tests also show that the models' coefficients are stable ([Appendix E](#)). Further, the speed of adjustment parameters of our models are negative and statistically significant, indicating that the variables in the estimated NARDL models have short-run dynamic and long-run equilibrium impacts.

The results of all four models show that fossil fuel energy consumption has positive and significant effects on CO₂ emissions in the short and long run. Based on these coefficients, a 1.0 percent increase in fossil fuel energy consumption increases per capita CO₂ emissions by a range of 0.29 percent and 0.37 percent. From the long-run coefficients, a 1.0 percent increase in fossil fuel consumption increases CO₂ emissions over a range of 0.39 percent and 0.53 percent. The results also show the short-run coefficients for carbon intensity range from 0.41 to 0.44 and are positive and statistically significant. The long-run coefficients for carbon intensity range between 0.57 and 0.66, are positive and comparatively much larger than their short-run counterpart. They are also statistically significant at the 1.0 percent level, indicating that a 1.0 percent increase in carbon intensity increases emissions in a range of 0.57 and 0.66 percent. Further, fossil fuel consumption due to expansion in domestic economic output combined with increased carbon intensity can lead to a notable growth in CO₂ emissions in Trinidad and Tobago.

The short-run coefficients of the import capacity variable are positive and statistically significant, ranging from 0.09 to 0.12 and significant at the 1.0 percent level, suggesting that a 1.0 percent improvement in the country's import capacity increases CO₂ emissions by up to 0.12 percent. Furthermore, the long-run coefficients (which range from 0.13 to 0.16) are also positive and statistically significant, indicating that a 1.0 percent improvement in import capacity results in a rise in CO₂ emissions by 0.16 percent in the long run.

With regard to Model 4, the coefficient of the 2008 global financial crisis dummy variable is positive and statistically significant but the coefficient size is small (0.03). In light of the coefficient size it may be reasonable to infer that the impact of fiscal and monetary policies on emissions remained stable and consistent, irrespective of the crisis.

The results of our models show that expansionary fiscal policy increases CO₂ emissions while contractionary fiscal policy decreases emissions in the short run. The short-run estimates are positive and range from 0.30 to 0.33, indicating that a 1.0 percent increase in fiscal spending or cut in revenues (or fiscal expansion) increases CO₂ emission by a range an average of 0.32 percent. A possible explanation is that higher fiscal spending incentivizes output through the aggregate demand channel, which increases CO₂ emissions. Additionally, different classes of expenditure, including spending on construction projects and capital imports, may impact CO₂ emissions differently, especially if they are not based on eco-friendly technologies. Further, spending on transfers and fuel subsidies can lead to more CO₂ emissions¹⁵.

In contrast, the models show that contractionary fiscal policy has decreasing effects on CO₂ emissions. The short-run coefficients of our models range from 0.31 to 0.33, implying that a fiscal contraction reduces emissions in the country by 0.31 percent. The magnitude of the coefficients is confirmed to be statistically the same based on the results of the Wald test ([Table 5](#)).

Our results show that expansionary fiscal policy increases CO₂ emissions, and contractionary fiscal policy decreases emissions in the long run. The long-run estimates show positive values ranging from 0.40 to 0.45 for expansionary fiscal policy, where all are significant at the 1.0 percent level. The result suggests that an expansionary fiscal policy of 1.0 percent would raise CO₂ emissions between 0.40 and 0.45 percent. However, the long-run estimates for contractionary fiscal policy (which ranges between 0.42 and 0.48) are positive and statistically significant at the 1.0 percent level, implying that a 1.0 percent fiscal contraction would lead to a reduction in CO₂ emissions by up to 0.48 percent over the long term. A possible explanation for the relatively larger long-term influence compared to short-term contractionary influence is that the reduction in spending reduces employment and economic activity, decreasing CO₂ levels. The overall finding is that expansionary and contractionary fiscal policies are emission-generating and may require the reform or development of fiscal strategies to improve climate mitigation efforts.

Contractionary monetary policy appears to also influence CO₂ emissions. The short-run estimates in our models are negative and range from values of 1.14 to 1.69 and the coefficients of all four models were statistically significant at the 1.0 percent level. The results suggest that a monetary contraction of 1.0 percent reduces emissions by an average of 1.4 percent. The long-run coefficients of the contractionary monetary policy are negative, ranging from 1.87 to 2.29 and are statistically significant at the 1.0 percent level. These estimates indicate that a contractionary monetary policy by 1.0 percent leads to a reduction in CO₂ emissions by an average of up to 2.0 percent in the long term.

When considering expansionary monetary policy, the coefficients of Model 2 and Model 3 are statistically significant, indicating that expansionary monetary policy leads to increases in emissions in the short run. The statistical significance of the long-run coefficients in Model 2 and Model 3 also suggests that expansionary monetary policy has some increasing effects on emissions in the long term.

We noticed that when the weights of the monetary policy index are adjusted to increase the importance of certain tools (such as the policy interest rate), the effects of monetary expansion and contraction have more notable impacts on emissions. Overall, based on our model results, measuring and accurately assessing the monetary policy stance and conditions in the domestic economy is crucially

¹⁵ The results are consistent with [Yuelen et al. \(2019\)](#).

Table 4

Econometric model results on the effects of fiscal and monetary policies on carbon dioxide emissions.

Variables (Short-run)	Model 1		Model 2		Model 3		Model 4	
Δ (Logged Energy Consumption Per Capita)	0.324 (0.083)	***	0.359 (0.075)	***	0.285 (0.067)	***	0.379 (0.089)	***
Δ (Logged Carbon Intensity)	0.436 (0.060)	***	0.433 (0.059)	**	0.411 (0.064)	**	0.477 (0.065)	***
Δ (Logged Expansionary Fiscal Policy)	0.326 (0.056)	***	0.292 (0.053)	***	0.302 (0.054)	***	0.324 (0.055)	***
Δ (Logged Contractionary Fiscal Policy)	0.331 (0.061)	***	0.309 (0.056)	***	0.315 (0.065)	***	0.333 (0.059)	***
Δ (Contractionary Monetary Policy)	-1.360 (0.416)	**	-1.685 (0.509)	***	-1.138 (0.466)	***	-1.492 (0.420)	***
Δ (Expansionary Monetary Policy)	-0.429 (0.305)		-0.513 (0.237)	**	-0.548 (0.275)	**	-0.136 (0.359)	
Δ (Logged Import Capacity)	0.095 (0.043)	**	0.121 (0.042)	***	0.116 (0.043)	***	0.105 (0.042)	***
Δ (Global Financial Crisis Dummy)							0.029 (0.007)	***
Error Correction Term(-1)	-0.728 (0.082)	***	-0.734 (0.083)	***	-0.717 (0.084)	***	-0.712 (0.082)	***
Variables (Long-run)								
C	-2.506 (0.556)	***	-2.753 (0.517)	***	-2.298 (0.473)	***	-3.059 (0.701)	***
Logged Energy Consumption Per Capita	0.446 (0.111)	***	0.488 (0.096)	***	0.398 (0.089)	***	0.531 (0.127)	***
Logged Carbon Intensity	0.600 (0.103)	***	0.590 (0.105)	***	0.572 (0.114)	***	0.669 (0.119)	***
Logged Expansionary Fiscal Policy	0.448 (0.049)	***	0.398 (0.045)	***	0.420 (0.046)	***	0.454 (0.049)	***
Logged Contractionary Fiscal Policy	0.454 (0.091)	***	0.422 (0.088)	***	0.439 (0.103)	***	0.468 (0.578)	***
Contractionary Monetary Policy	-1.868 (0.551)	**	-2.295 (0.647)	***	-1.921 (0.617)	***	-2.092 (0.503)	***
Expansionary Monetary Policy	-0.589 (0.425)		-0.699 (0.337)	***	-0.763 (0.397)	**	-1.192 (0.065)	
Logged Import Capacity	0.131 (0.063)	**	0.165 (0.063)	***	0.163 (0.064)	**	0.147 (0.028)	**
Global Financial Crisis Dummy							0.041 (0.701)	
Model Diagnostics								
R ²	0.797		0.799		0.790		0.807	
Adjusted R ²	0.792		0.799		0.785		0.799	
LM- Serial Correlation Test	0.246		0.677		0.810		0.396	
Brush-Pagan Godfrey Heteroscedasticity Test	0.080		0.110		0.100		0.121	
Jargue-Bera normality Test	0.664		0.453		0.312		0.831	
Ramsey Reset Test	0.122		0.229		0.124		0.203	
Durbin Watson Statistic	2.110		2.090		2.040		2.140	

Note: *, ** and *** indicate a 10% level, 5% level and 1% level of significance, respectively. The diagnostic test results are probability values.

Source: Authors' estimates using Eviews.

Table 5

Wald test results on the symmetric relationship between expansionary and contractionary policy.

H ₀	H ₁	F-statistic	Decision
Model 1			
-C(5)/C(2)=C(6)/C(2)	-C(5)/C(2)≠C(6)/C(2)	2.017	Long-run symmetry exists between expansionary and contractionary fiscal policy
-C(7)/C(2)=C(8)/C(2)	-C(7)/C(2)≠C(8)/C(2)	0.005	Long-run symmetry exists between expansionary and contractionary monetary policy
Model 2			
-C(5)/C(2)=C(6)/C(2)	-C(5)/C(2)≠C(6)/C(2)	1.679	Long-run symmetry exists between expansionary and contractionary fiscal policy
-C(7)/C(2)=C(8)/C(2)	-C(7)/C(2)≠C(8)/C(2)	2.307	Long-run symmetry exists between expansionary and contractionary monetary policy
Model 3			
-C(5)/C(2)=C(6)/C(2)	-C(5)/C(2)≠C(6)/C(2)	1.448	Long-run symmetry exists between expansionary and contractionary fiscal policy
-C(7)/C(2)=C(8)/C(2)	-C(7)/C(2)≠C(8)/C(2)	0.238	Long-run symmetry exists between expansionary and contractionary monetary policy
Model 4			
-C(5)/C(2)=C(6)/C(2)	-C(5)/C(2)≠C(6)/C(2)	2.055	Long-run symmetry exists between expansionary and contractionary fiscal policy
-C(7)/C(2)=C(8)/C(2)	-C(7)/C(2)≠C(8)/C(2)	0.104	Long-run symmetry exists between expansionary and contractionary monetary policy

Note: *** depicts significance at 1% level

Source: Eviews output.

important to assess its impact on emissions, and is an area for further analysis. The finding contributes to the mixed results found in the literature.

Although government revenue and expenditure were considered in this study, it is possible that the use of alternative weightings and variables in the derivation of the fiscal policy index may provide additional insights on the fiscal policy stance and allow for a deeper understanding of the effects of fiscal policies on emissions.

5.2. Assessing the fiscal and monetary policies-carbon dioxide dynamic multipliers

The asymmetric dynamic relationships between the policy variables and CO₂ emissions have been further analyzed by plotting the multiplier effects (Figs. 5 and 6). The solid black line (dashed black lines) in Fig. 5 describes the adjustment of CO₂ emissions to a unitary change in fiscal policy over 15 years. The asymmetry lines (red dashed lines) reflect the difference between the positive and negative impact multipliers over 15 years. Fig. 5 shows that a fiscal expansion has an increasing effect on CO₂ emissions. In contrast, a fiscal contraction decreases emissions over the forecast horizon. It can also be seen that expansionary and contractionary fiscal policy display some symmetric behavior, as the magnitude of the effect of a fiscal expansion on emissions is almost the same as a fiscal contraction.

In the case of monetary policy, the solid black line (dashed black lines) in Fig. 6 describes the adjustment of CO₂ emissions to a unitary contractionary and expansionary change in monetary policy over 15 years. Fig. 6 shows that a contractionary monetary policy decreases CO₂ emissions over the 15-year forecast horizon. An expansionary policy has an increasing effect on emissions, but the magnitude of the effect is relatively much smaller when compared to a contractionary shock. Fig. 6 also shows expansionary and

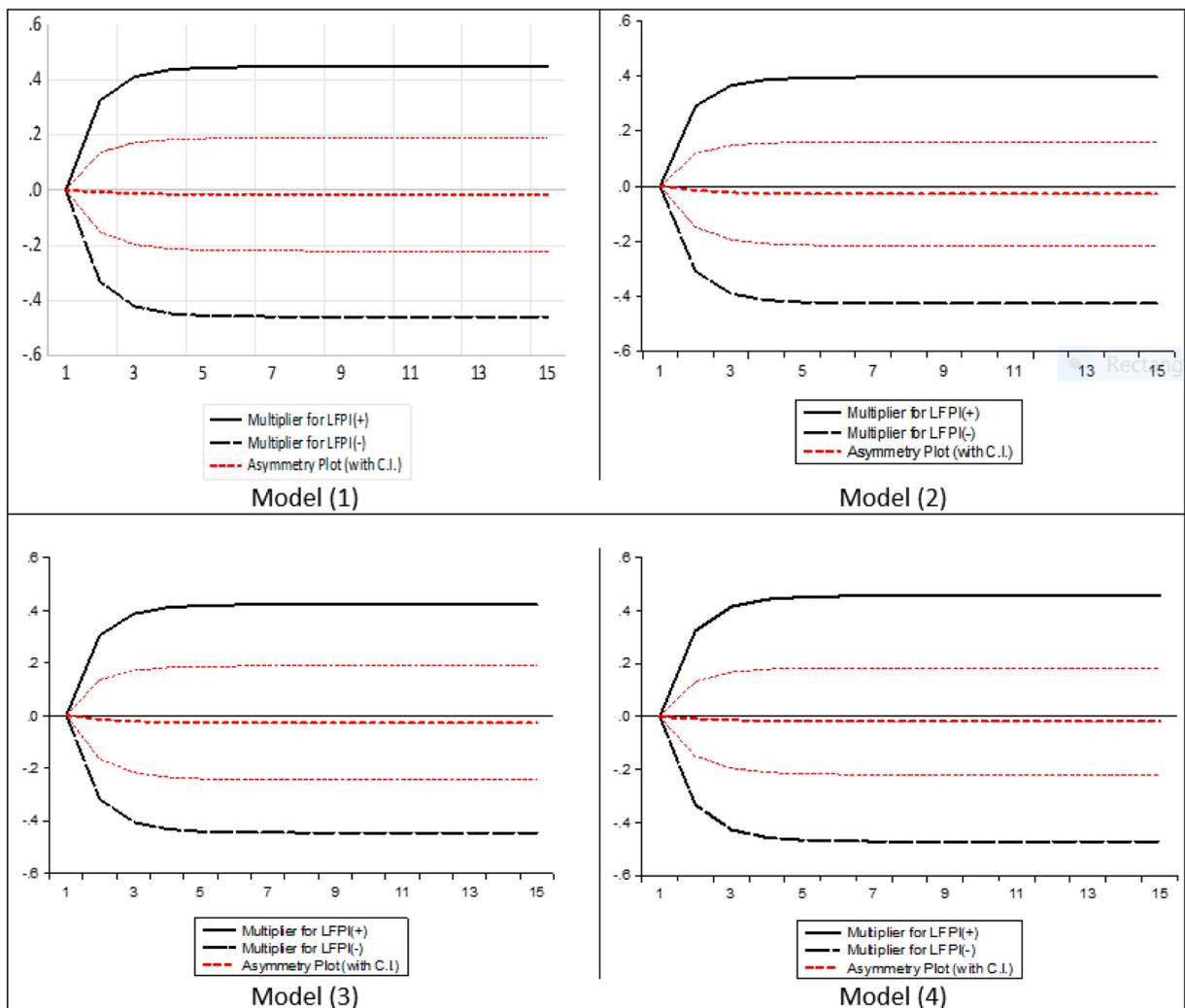


Fig. 5. Fiscal policy-carbon dioxide dynamic multipliers. Source: Authors' calculations.

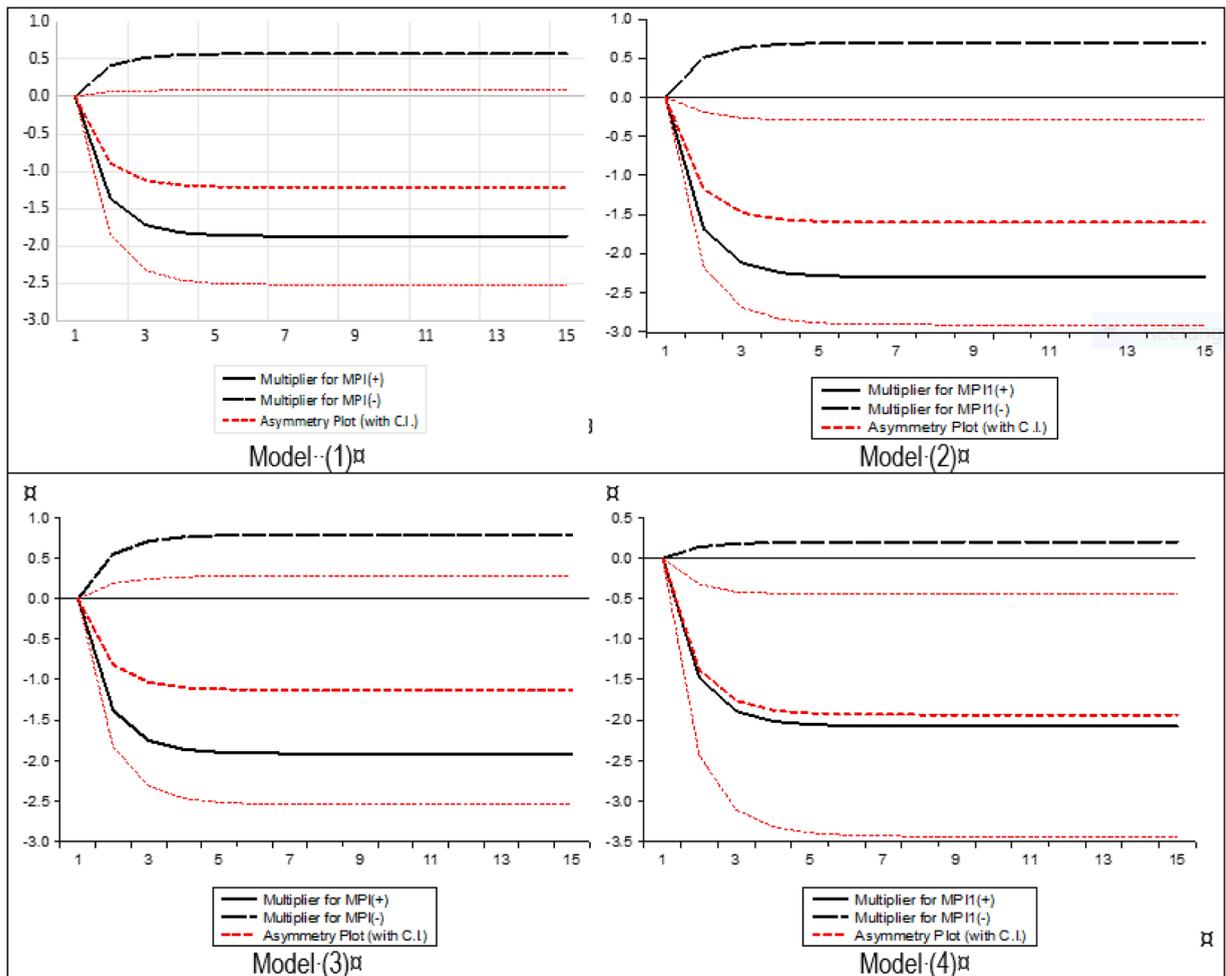


Fig. 6. Monetary policy–carbon dioxide dynamic multipliers. Source: Authors’ calculations.

contractionary monetary policy displaying asymmetric behavior.

6. Conclusion and recommendations

This paper’s primary purpose was to examine the economic effects of fiscal and monetary policies and CO₂ emissions, with the consort of some control variables (that is, fossil fuel energy consumption, carbon intensity of economic activity and import capacity) for Trinidad and Tobago. The application of the four NARDL models confirms a long-run causal relationship among the variables. Further, the cointegrating parameter is negative and statistically significant, indicating that the variables in the estimated NARDL models have short-run dynamic and long-run equilibrium impacts.

In examining the short-run and long-run dynamics, it is noteworthy that the impact of fossil fuel energy consumption, carbon intensity and import capacity on CO₂ emissions are positive and statistically significant. A key feature is that the impact on CO₂ emissions is greater in the long run than in the short run. According to the NARDL model results, expansionary fiscal policy contributes to increases in CO₂ emissions, while contractionary fiscal policy decreases CO₂ emissions. This finding implies that fiscal policy is not fully oriented toward reducing CO₂ emissions and some policy actions risk impacting domestic economic activity. Monetary policy was found to have some effects on CO₂ emissions in the short and long run based on adjustments to the weights for the monetary policy. The finding contributes to the results found in the literature, reflecting the complex channels through which fiscal and monetary policies impact the economy.

The paper’s findings carry useful implications for governments, central banks, finance ministries, policymakers, and environment regulating agencies. Firstly, since higher fiscal spending leads to greater CO₂ emissions and is also a major requisite for improving growth and employment outcomes, there is a need for climate-related green policies to promote efficient use of fossil fuels and a scaling

up of renewable energy to maximize output while keeping CO₂ emissions down, especially in major emitting sectors¹⁶. The industry, power generation, and transport sectors have been identified as the larger contributing sectors to CO₂ emissions in Trinidad and Tobago; therefore, tailoring policies to reduce or optimize fossil fuel consumption in these sectors can contribute to climate change mitigation. For example, prioritizing public spending that promotes cleaner energy consumption in the transportation sector may reduce CO₂ emissions. In Trinidad and Tobago, using compressed natural gas as an alternative and cost-effective fuel in public and private transportation is already being implemented¹⁷. In addition, there are incentives for efficient energy use and renewable energy production¹⁸. However, there is potential to increase industry usage of renewable energy within the energy mix. In the 2023 national budget statement, the Government stated its intention to develop a renewable energy policy and explore green hydrogen as a fuel.

Apart from ensuring a greater composition of green public spending, the Government could also consider a mix of instruments such as an emissions trading system (ETS), a carbon tax and public guarantees to reduce CO₂ emissions. The Ministry of Finance is exploring carbon pricing approaches for Trinidad and Tobago, such as implementing a carbon tax and/or developing an ETS. Although there is widespread support for carbon taxes or ETSs as possible effective responses to climate change, these policies have their advantages and disadvantages which should be assessed in the Trinidad and Tobago context. Similarly, if implemented successfully, public guarantees can incentivize firms to invest in clean technologies. Energy subsidy reform, along with incentives such as the full removal of taxes on hybrid and electric motor vehicles, can reduce fossil fuel energy consumption and, by extension, CO₂ emissions.

Given the dual causation, that is, revenue and expenditure both contributing to CO₂ emissions¹⁹, decoupling economic growth from fossil fuel consumption should be an imperative. Expenditure could be directed to building renewable energy capacity and transforming economic sectors to low-carbon status. Further, spending on strengthening the development, enforcement and effectiveness of environmental regulations can reduce CO₂ emissions and improve environmental quality through the environmental regulation channel.

This study also has implications for monetary policy due to its potential effects on CO₂ emissions. Monetary policy can contribute to climate change adaptation and mitigation. Green monetary policy via a “central bank green interest rate” to indicate the funding costs available to commercial banks to finance private sector green investments²⁰ could be investigated. Some policymakers advance that green monetary policy instruments can convolute the role of central banking and, by extension, monetary policy objectives. However, some central banks recognize the urgency of climate change action and are taking steps to implement green monetary policy. Additionally, several central banks have started integrating climate-related shocks (physical and transition risks) into their financial risk frameworks. The NGFS has been successful in scaling up green finance and helping central banks strengthen their analytical orientation to model the impact of climate change on the financial system (NGFS, 2022). The Central Trinidad and Tobago, as a member of the NGFS, should continue to leverage the expertise available to build capacity in these areas. [Appendix Table F](#) briefly discusses potential green policies that can be explored to alleviate the adverse effects of fiscal and monetary policies on emissions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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¹⁶ Trinidad and Tobago became a signatory to the Paris Agreement (2015) in 2018. Under this Multilateral Environmental Agreement (MEA), the country has agreed to cut greenhouse gas emissions in the power generation, transportation and industrial sectors. It has developed a Carbon Reduction Strategy to achieve the target. This commitment is known as our Nationally Determined Contribution (NDC), which has two parts: (i) a 15.0 percent reduction in cumulative emissions from the major contributing sectors and (ii) an unconditional 30.0 percent reduction in emissions from public transportation.

¹⁷ The use of compressed natural gas as a transport fuel is widely used across the world. Although compressed natural gas is a fossil fuel, it is the cleanest burning fuel at the moment in terms of its emission of greenhouse gases. See the United Nations Climate Change and Technology Network website for additional information: Compressed Natural Gas (CNG) as fuel | Climate Technology Centre & Network | 1184949 (ctc-n.org)

¹⁸ Efficient energy use and reduction in greenhouse gas emissions is being encouraged through the provision of an increase in electricity rebates to households whose electricity bill is lower than \$300.00, the removal of customs duties, motor vehicle tax and Value Added Tax (VAT) on battery powered electric vehicles and several fiscal incentives through the compressed natural gas programme. Additionally, the Government is advancing its renewable energy goals with plans for the construction of two solar Photo Voltaic plants through build- own-operate schemes, feeding 92.2 megawatts and 20.0 megawatts of solar power onto the national grid at Couva and Trincity, respectively.

¹⁹ Since revenue increases are typically associated with higher fossil fuel consumption and public spending (given the procyclical nature of fiscal policy), which generates CO₂ emissions, directing expenditures towards renewable energy production can help transition the local economy away from fossil fuels to sustainable energy alternatives.

²⁰ The proposed central bank green interest rate is a policy rate set below the Bank’s traditional policy rate, which can be utilized for short-term borrowing by commercial banks that re-lend for private sector green projects. Using a green policy interest rate could ensure that the financing cost of green investment is not adversely impacted by strong monetary policy contractions and will also facilitate low-cost liquidity flows to commercial banks wishing to commit funds for long-term green projects.

Appendix A. Further details on prior studies and data relating to Trinidad and Tobago

Table A1

Prior studies on the effects of fiscal and monetary policies on carbon dioxide emissions.

Author	Sample Period	Countries	Method	Results
Qingquan et al. (2020)	1990-2014	Selected Asian Economies	FMOLS and DOLS	EMP increases CO _{2e} CMP decreases CO _{2e}
Isiksal et al.(2019)	1980-2014	Turkey	ARDL	MP negatively impacts CO _{2e}
Pradeep (2021)	1971-2014	India	ARDL	MP positively impacts CO _{2e}
Bernauer and Koubi (2006)	1971-1996	42 countries	OLS	FP increases SO _{2e}
Yuelan et al. (2019)	1980-2016	China	ARDL	FP increases CO _{2e} LR
Lopez et al. (2011)	1986-1999	38 countries	OLS	FP increases SO ₂
Katircioglu and Katircioglu (2018)	1960-2013	Turkey	ARDL	FP decreases CO _{2e}
Halkos and Paizanos (2013)	1980-2000	77 countries	FE, DFE	FP insignificant effect on CO _{2e}
Halkos and Paizanos (2016)	1973 - 2013	United States	VEC	EFP decreases CO _{2e}
Yilanci and Pata. (2021)	1875-2016	G7 countries	bootstrap causality	FP reduces CO _{2e}
Muhafidin (2020)	1973-2018	Indonesia	ARDL	MP positively impacts CO _{2e} FP positively impacts CO _{2e}
Chishti et al. (2021)	1985-2014	BRICS economies	KW, POLS, DOLS, FMOLS, PMG (ARDL)	EFP and EMP increases CO _{2e} CFP and CMP decreases CO _{2e}
Ullah et al. (2021)	1985-2019	Pakistan	NARDL	CMP decreases CO _{2e} EMP increases CO _{2e} EFP and CFP decrease CO _{2e} (LR)
Mahmood et al. (2022)	1990-2019	GCC region	PMG, FMOLS, DOLS	FP increases CO _{2e} in SR and LR MP increases/decreases CO _{2e} SR/LR
Mughal et al. (2021)	1990-1999	ASEAN economies	NARDL	CMP decreases CO _{2e} (LR), EMP increases CO _{2e} (LR and SR), EFP decreases CO _{2e} (LR), EFP increases CO _{2e} (SR), CMP and CFP insignificant (SR)

Source: Authors' compilation.

Abbreviations: ARDL, autoregressive distributed lag model; ASEAN, Association of Southeast Asian Nations; BRICS, Brazil, Russia, India, China, & South Africa; CFP, contractionary fiscal policy; CMP, contractionary monetary policy; DOLS, dynamic ordinary least squares; EFP, expansionary fiscal policy, EMP, expansionary monetary policy; FMOLS, fully-modified ordinary least squares; FE, fixed effects; FP, fiscal policy; GMM, generalized method of moments; GCC, Gulf Cooperation Countries; LICs, Low income countries; LR, long-run; MENA, Middle East and North Africa; MCT, Maki cointegration test; MP, monetary policy; NARDL, non-linear autoregressive distributed lag model; POLS, panel ordinary leased squares; PMG, pooled mean regression; RE, random effects; SR, short-run; VECM, vector error correction model; LIC, Low-Income Countries; OLS, ordinary least squares.

Table A2

Correlation coefficients of model variables.

VARIABLES	CO _{2e} PC	ECPC	CIN	GREVPC	GSPC	GDPPC	FPI	BR	TBILL	RR	MPI	IMC
CO _{2e} PC	1.00	0.96	0.43	0.94	0.94	0.74	0.95	-0.18	-0.47	0.35	-0.10	0.75
ECPC	0.96	1.00	0.45	0.89	0.88	0.67	0.90	-0.14	-0.39	0.32	-0.07	0.71
CIN	0.26	0.28	1.00	0.02	0.04	-0.25	0.03	0.68	0.45	0.71	0.74	0.13
GREVPC	0.94	0.89	0.10	1.00	0.96	0.90	0.99	-0.27	-0.50	0.25	-0.19	0.77
GSPC	0.94	0.88	0.10	0.96	1.00	0.91	0.99	-0.34	-0.62	0.29	-0.24	0.68
GDPPC	0.97	0.94	-0.25	0.94	0.96	1.00	0.96	-0.23	-0.52	0.35	-0.14	0.75
FPI	0.95	0.90	0.11	0.99	0.99	0.91	1.00	-0.31	-0.57	0.28	-0.22	0.73
BR	-0.18	-0.14	0.68	-0.27	-0.34	-0.58	-0.31	1.00	0.87	0.54	0.95	-0.04
TBILL	-0.47	-0.39	0.45	-0.50	-0.62	-0.73	-0.57	0.87	1.00	0.26	0.83	-0.27
RR	0.35	0.32	0.71	0.25	0.29	-0.02	0.28	0.54	0.26	1.00	0.74	0.21
MPI	-0.10	-0.07	0.74	-0.19	-0.24	-0.51	-0.22	0.95	0.83	0.74	1.00	-0.03
IMC	0.75	0.71	0.19	0.77	0.68	0.63	0.73	-0.04	-0.27	0.21	-0.03	1.00

Source: Authors' calculations.

Table A3

Results of the descriptive statistics.

VARIABLES	CO _{2e} PC	CIN	ECPC	GREVPC	GSPC	FPI	GDPPC	BR	TBILL	RR	MPI	IMC
Mean	20.47	103.98	94470.74	19.84	20.75	466.30	20580.72	8.15	4.77	14.37	8.68	1.31
Median	16.13	110.69	70855.28	15.23	15.28	350.60	19183.46	7.00	4.52	15.00	7.71	1.24
Maximum	35.64	161.13	176079.8	52.66	47.91	1086.01	37359.01	13.00	11.81	24.00	15.40	2.16
Minimum	8.28	46.76	44127.77	3.906	4.79	100.00	10158.43	4.75	0.060	5.00	4.41	0.72
Std. Dev.	8.83	31.64	47810.97	12.68	12.89	290.55	7981.40	2.84	3.29	4.66	2.91	0.35
Skewness	0.48	-0.11	0.53	0.79	0.63	0.67	0.42	0.74	0.48	-0.23	0.96	0.52
Kurtosis	1.76	2.08	1.61	2.46	1.94	2.08	2.07	2.08	2.42	2.42	2.83	0.27
Jarque-Bera	5.25*	1.90	6.48**	5.98*	5.74*	5.64*	3.36	6.54**	2.74	1.193	8.02**	2.59
Probability	0.07	0.387	0.039	0.058	0.057	0.059	0.18	0.037	0.254	0.550	0.014	0.000
Observations	51	51	51	51	51	51	51	51	51	51	51	51

Note***, **, and * represents the values are significant at 1%, 5%, and 10%, respectively.

Source: Authors' calculations.

Appendix B. Unit root and non-linearity tests

Time series data analysis requires the investigation of the stationarity properties of the variables to decide the most appropriate method. We employ the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests to estimate stationarity. The results are recapped in Appendix Table B1, and the outcomes show that all variables are integrated of order one I(1) except for IMC, which shows evidence of stationarity. However, none of the variables are integrated of order I(2). However, it should be noted that the ADF and PP may give misleading results if the time series contain structural breaks.

Further, when a structural break is large, and the sample date is small, these tests have a lower ability to determine the stationarity property of the time series accurately. That is, it is more likely that the null hypothesis will not be rejected. Therefore, we estimate the extent of the non-stationary using the Augmented Dickey-Fuller (Structural Breakpoint) unit root test, designed to test unit root in the presence of a single break in the time series due to a change in the structure of the economy. The results for the variables in levels and first differences are presented in Appendix Table B2. Thus, even considering a structural break, the series displayed the same stationarity status compared to the standard unit root tests in almost all instances.

Table B1

Results of Augmented Dickey-Fuller (ADF) and Phillips Peron (PP) unit root tests.

Variables	Levels		First Difference	
	ADF	PP	ADF	PP
Log Carbon Emissions per capita	-1.58	-1.65	-7.63***	-7.61***
Log Energy Consumption per capita	-1.02	-1.17	-6.24***	-6.29***
Log Carbon Intensity	-2.09	-1.92	-8.27***	-8.46***
LogFiscal Policy Index	-2.27	-1.94	-5.28***	-5.42***
Monetary Policy Index	-1.11	-1.32	-5.50***	-5.52***
Log Import Capacity	-3.64**	-3.57**	-6.29***	-12.99***

Note: *, ** and *** indicate significance at the 10%, 5% and 1%, respectively. For the ADF and PP, H₀ = Variable has a unit root and H₀ = Variable is stationary for the KPSS test.

Critical values for the ADF and PP (level) tests are -4.15 (1%), -3.502 (5%), and -3.18 (10%).

Critical values for the ADF and PP (first difference) tests are -3.57 (1%), -2.92 (5%), and -2.59 (10%).

Source: Authors' calculations using Eviews 9.

Table B2

Results of Augmented Dicky-Fuller unit root test with structural break.

Notation	At Level			At First Difference			Result
	Break Date	T-Stat	P-value	Break Date	T-Stat	P-value	
Log Carbon Emissions per capita	2002	-2.52	>0.98	1976	-9.08***	<0.01	I(1)
Log Energy Consumption per capita	2015	-1.65	>0.99	1979	-6.42***	<0.01	I(1)
Log Carbon Intensity	2003	-4.31	0.33	1976	-8.81***	<0.01	I(1)
Log Fiscal Policy Index	1982	-2.89	0.97	1980	-5.89***	<0.01	I(1)
Monetary Policy Index	2001	-4.58	0.20	2002	-6.53***	<0.01	I(1)
Log Import Capacity	2004	-4.56	0.21	2006	-6.85***	<0.01	I(1)

Note: Critical values (Level: Trend and Intercept) are -5.34 (1%), -4.85 (5%), -4.60 (10%) - If T-stat > critical value, reject $H_0:\delta=0$ (Has a Unit Root)
 Critical values (1st Diff: Intercept only) are -4.94 (1%), -4.44 (5%), and -4.19 (10%) - If T-stat > critical value, reject $H_0:\delta=0$ (Has a Unit Root)

Break Selection Criteria: Minimize Dicky-Fuller t-statistic, Automatic Selection based on F-statistic (max lag = 2, lag p-value=0.10)

The presence of multiple structural breaks can indicate non-linearity in the data, and therefore the NARDL technique to analyse non-linear relationships among the variables. We confirm the non-linearity in the data by conducting BDS tests (Brock Dechert, Scheinkman and LeBaron, (1996)) of all the variables in the model. The test results in Appendix Table B3 indicate non-linearity in all the variables used in the NARDL model.

Table B3

Results of Dechert, Scheinkman and LeBaron (BDS) test for non-linearity of variables included in the Non-linear Autoregressive Distributed Lag models.

Variables	m=2	m=3	m=4	m=5	m=6
Log Carbon Emissions per capita	0.17*	0.29*	0.37*	0.42*	0.46*
Log Energy Consumption per capita	0.19*	0.32*	0.39*	0.45*	0.48*
Log Carbon Intensity	0.14*	0.23*	0.30*	0.34*	0.37*
Log Fiscal Policy Index	0.18*	0.29*	0.37*	0.41*	0.43*
Monetary Policy Index	0.15*	0.26*	0.32*	0.34*	0.34*
Log Import Capacity	0.06*	0.11*	0.14*	0.15*	0.14*

Note: * represents the 1% level of significance. Embedding dimensions =m (probability)

Source: Authors calculation using Eviews 9.

Appendix C. Testing for multicollinearity

Appendix Table C1 shows the variance inflation factor for the chosen specification, which is less than 5, suggesting no multicollinearity problem in the model. Therefore, the estimated results can be used to understand macroeconomic policy effects on CO₂ emissions in Trinidad and Tobago.

Table C1

Results of Variance Inflation Factor.

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
Log Carbon Emissions per capita	0.001376	1860.753	3.545546
Log Energy Consumption per capita	0.003684	913.4332	2.934237
Log Carbon Intensity	0.000768	288.7931	3.410743
Log Fiscal Policy Index	5.25E-06	24.53887	2.443097
Monetary Policy Index	0.002628	682.6094	1.955945
C	0.017536	977.3537	NA

Source: Eviews output

Appendix D. NARDL bounds test for cointegration

The results of the cointegration test based on the NARDL bound testing method are presented in Appendix Table D1. The critical bounds by Pesaran et al. (2001) are not considered appropriate for this analysis given that they are estimated from a large sample (Narayan 2005), while this study uses a relatively small sample of 51 observations (1970 to 2020). Therefore, the critical values for evaluating the null hypothesis are taken from Narayan (2005). Narayan (2005) computed two sets of critical values: lower bounds I(0) and upper bounds critical values I(1) from sample sizes ranging from 30 to 80. Appendix Table D1 suggests that the F-statistics in all four models are greater than the upper bound from Narayan (2005) at the 1.0 percent significance level. The study, therefore, rejects the null hypothesis of no cointegration among the variables. This outcome suggests a long-run causal relationship between CO₂ emissions, fossil energy consumption, carbon intensity, fiscal policy, monetary policy, and import capacity.

Table D1
Results of Bounds Test.

Specification	Optimal Lag			F-Statistic
(Model 1) F[LCO _{2e} PC LECPC, LCIN, LFPI, MPI, LIMC]	ARDL(1, 0, 0,0,0,0,0)			20.07***
Critical value bounds	1%	5%	10%	
/0 bound (k=7, n=50)	3.498	2.593	2.205	
/1 bound (k=7, n=50)	5.149	3.941	3.421	
(Model 2) F[LCO _{2e} PC LECPC, LCIN, LFPI, MPI, LIMC]	ARDL(1, 0, 0,0,0,0,0)			19.05***
Critical value bounds	1%	5%	10%	
/0 bound (k=7, n=50)	3.282	2.45	2.099	
/1 bound (k=7, n=50)	4.73	3.65	3.181	
(Model 3) F[LCO _{2e} PC LECPC, LCIN, LFPI, MPI, LIMC]	ARDL(1, 0, 0,0,0,0,0)			19.31***
Critical value bounds	1%	5%	10%	
/0 bound (k=7, n=50)	3.498	2.593	2.205	
/1 bound (k=7, n=50)	5.149	3.941	3.421	
(Model 4) F[LCO _{2e} PC LECPC, LCIN, LFPI, MPI, LIMC, GFC_DUM]	ARDL(1, 0, 0,0,0,0,0)			19.68***
Critical value bounds	1%	5%	10%	
/0 bound (k=7, n=50)	3.498	2.593	2.205	
/1 bound (k=7, n=50)	5.149	3.941	3.421	

Note: Optimal lag length for all NARDL models are based on Schwarz Information Criterion (SIC); unrestricted intercept and no trend; *, ** and *** indicate 10% level, 5% level and 1% level of significance, respectively.

Appendix E. Structural break adjusted CUSUM and CUSUMSQ plots

Appendix Fig. E.1 shows the structural break adjusted CUSUM and CUSUMSQ statistics. The figures are within the critical bounds for the 5.0 percent significance level, indicating that the coefficients of the estimated NARDL model specifications are stable.

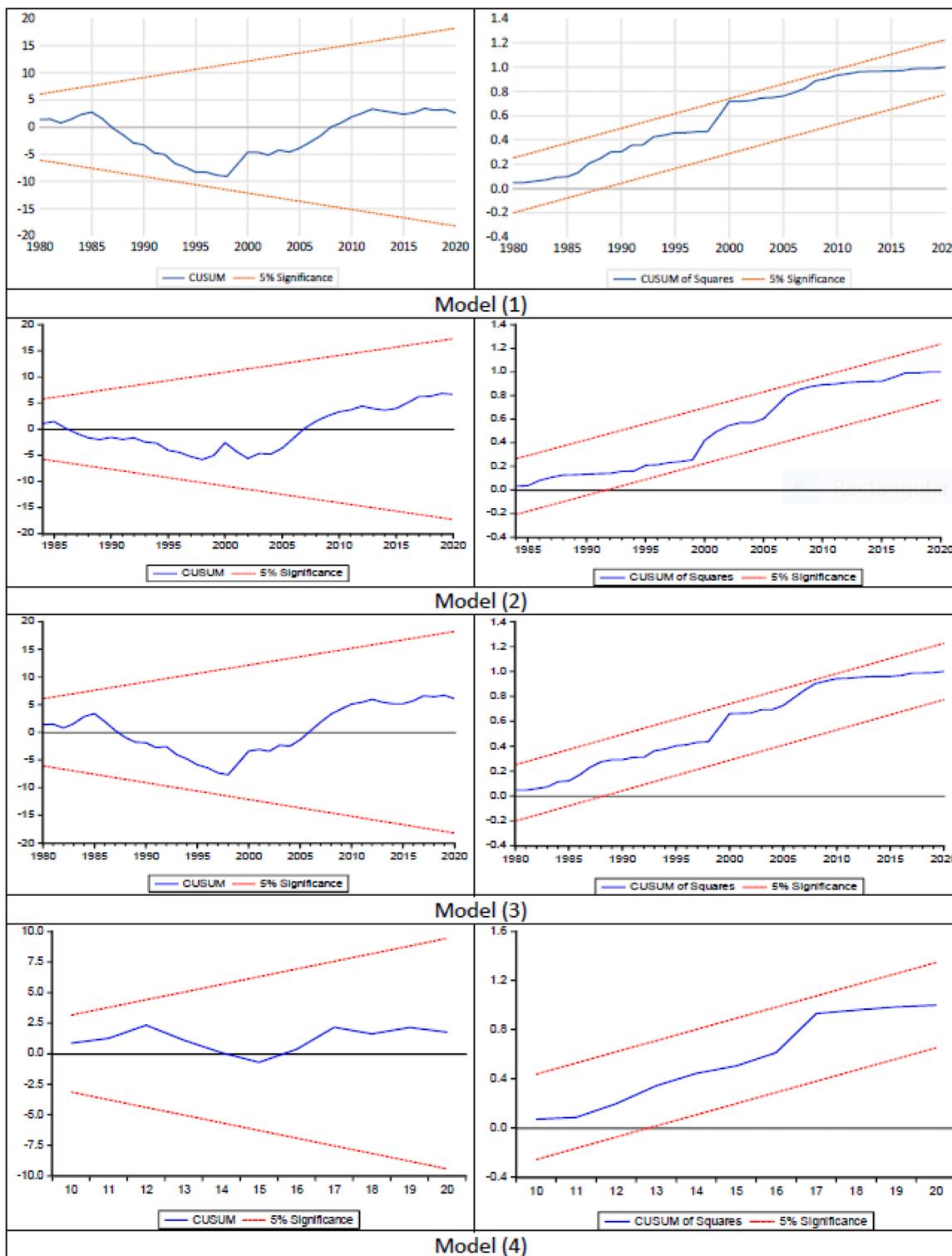


Fig. E.1. CUSUM and CUSUMSQ Plots for NARDL Model.
Source: Eviews output.

Appendix F. The effects of green fiscal and monetary policy instruments on emissions

The economic literature has suggested that greater use of green fiscal and monetary policy instruments can limit the adverse environmental impacts of fiscal and monetary stance. By introducing green fiscal and monetary policy instruments, it is possible for expansionary and contractionary fiscal and monetary policy to have lower adverse effects on CO₂ emissions or even contribute to reducing emissions.

Green fiscal policy falls into four broad categories: public spending and investment, public-private partnerships (PPPs), price policies (taxation and incentives), and public guarantees, which are targeted to reduce emissions such as CO₂.

Several studies have found that green public spending and investment reduced CO₂ emissions. For instance, [Ahmed et al. \(2021\)](#) argued that government spending on clean energy infrastructure might reduce CO₂ emissions. The authors investigated the case of Japan using data from 1974-2017 and found that government investment in clean energy development projects and nuclear energy effectively reduced CO₂ emissions. [Zhang et al. \(2021\)](#) also argued that public spending on green energy technologies might promote green production innovation techniques and sustainable development. Further, [Neves et al. \(2020\)](#) noted that policies to promote renewable energy and foreign direct investment reduced emissions, boosting the emissions profile of several EU countries.

Similarly, PPPs can also be effective in reducing CO₂ emissions in countries. According to [Neves et al. \(2020\)](#), approximately 70.0 percent of global greenhouse gas emissions are generated by the construction and operation of physical infrastructure. Although this is part of the problem concerning climate change, it can be part of the solution to greenhouse gas mitigation. New opportunities for sustainable infrastructure are now available due to technological advances that have been reducing the costs of low-carbon alternatives such as renewable energy. If appropriately designed and implemented, PPPs can allow governments to improve infrastructure investment while reducing public spending ([Arezki & Belhaj, 2019](#)). However, PPP projects have been experiencing severe challenges in many countries due to weaknesses such as insufficient legal frameworks, project selection and costing capabilities ([Batjargal and Zhang, 2021](#); [Innes, 2018](#)).

According to economic theory, governments should use environmental taxes to discourage economic activities that generate negative externalities ([Pigato, 2018](#)). Several studies have sought to assess the effectiveness of a carbon tax on CO₂ emissions. A carbon tax is a tariff on fossil fuels and other products to reduce greenhouse gas emissions such as CO₂. [Hashmi and Alam \(2019\)](#) found that environmental taxes reduced CO₂ emissions in the Organization for Economic Cooperation and Development (OECD) countries using data from 1999 to 2014. Similarly, [Solaymani \(2017\)](#) investigated the role of taxes on emissions in Malaysia and found that carbon and energy taxes helped reduce emissions. [Khan et al. \(2021\)](#) reported that carbon taxes, renewable energy, and innovations helped reduce CO₂ emissions. [Mardones and Flores \(2018\)](#) reported that carbon taxes helped accelerate cleaner industrial use of energy in Chile and reduced emissions.

However, carbon pricing is sometimes ineffective in reducing emissions. [Mardones and Flores \(2018\)](#), which analyzes the impact of variations on the carbon tax per ton of CO₂, found that taxes that are too low or too high would contribute to raising government revenue but not reducing CO₂ emissions. [Fay et al. \(2015\)](#) also pointed out that prices can be ineffective in reducing CO₂ emissions when low-carbon alternatives and long-term credibility are absent. Further, carbon taxes that only contain a revenue component are less likely to effectively reduce emissions. Therefore, successful carbon pricing regimes should contain revenue generation and expenditure components ([Fay, et al., 2015](#)). Implementing a carbon tax of US\$40.00 per ton of CO₂ on fossil fuels in the Latin American and Caribbean (LAC) region could generate an estimated US\$69.0 billion per year ([Coady et al. \(2019\)](#) and [Delgado, Eguino, and Lopes \(2021\)](#)).

Fiscal authorities can facilitate greenhouse gas reduction through incentives such as public guarantees. However, although public guarantees can reduce emissions, fiscal challenges in some countries may prohibit implementing this measure, requiring innovative financing methods through local capital markets, such as green bonds or financial instruments that support green initiatives ([Delgado, Eguino, and Lopes, \(2021\)](#)). Mobilizing public and private investment while developing capital markets are crucial in LAC countries since tremendous potential exists to innovate with financial instruments and simultaneously deepen local capital markets. [Delgado, Eguino, and Lopes \(2021\)](#) suggest that guarantees can either: (i) encourage commitments to pay a debt related to a climate change activity or (ii) serve as instruments to improve credit profiles when structuring sustainable infrastructure projects.

In addition to public guarantees, the regional literature conveys that eliminating or reforming energy subsidies can incentivize economies to reduce greenhouse gas emissions. Government subsidies have helped maintain artificially low fuel prices in the region. Governments in the LAC region spend approximately 1.0 percent of GDP subsidizing energy consumption. According to the IMF, eliminating energy subsidies, imposing taxes to address negative externalities, and a carbon tax could generate an estimated US\$224.0 billion per year for the LAC region. These savings could amount to more than 2.0 percent of GDP in 27 countries and more than 10.0 percent in Guyana, the Bolivarian Republic of Venezuela, and Trinidad and Tobago ([Delgado, Eguino, and Lopes, \(2021\)](#)). Environmental taxes and reduced energy subsidies can potentially reduce informality, tax evasion, and corruption ([Bento, Jacobsen, & Liu, 2018](#)).

More recently, with the introduction of large-scale fiscal packages during the pandemic there has been calls for “greening” fiscal policy to meet the dual goals of economic recovery and environmental sustainability. As a result, several researchers and international organizations have attempted to assess the “greenness” of fiscal policy responses. [Eltokhy et al. \(2021\)](#) take stock of the contributions made by various fiscal policy trackers developed during the COVID-19 pandemic. The study identified the strengths and weaknesses in the methodology of policy trackers and draws on lessons for assessing the climate impact of fiscal policy. Utilizing predominantly the IMF’s Green Tracker which categorizes climate-relevant policy measures according to a set of 37 policy archetypes and captures the expected climate impact of fiscal interventions along five key sectors: energy, transport, industry, agriculture, and waste management the paper finds that the green content of the crisis response has been generally small and/or overshadowed by measures supporting

climate-harmful activities. Additionally, the study notes that continually tracking the “greenness” of policy measures remains imperative to hold governments accountable for their actions on climate change.

In light of the uncertainty involving the effects of conventional monetary policy on CO₂ emissions, the literature has suggested greening monetary policy to circumvent the adverse impact of changes in the monetary policy stance on environmental emissions. Recent studies suggest that central banks are actively contemplating developing and using climate-related green monetary policy measures to contribute to CO₂ mitigation. Some central banks have noted the urgency of climate change action and are already taking steps to implement green monetary policy. As countries decarbonize and central banks take on a more active role in climate change mitigation, climate-sensitive monetary policies should be considered without compromising the primary objective of price stability. Examples of green monetary policy include adapting central banks’ collateral frameworks and using environmental, social and governance criteria in their large-scale asset purchases (Coeure, 2018). These measures ensure that climate risks are adequately assessed and reflected on collateral frameworks and asset purchases. Central banks could also actively purchase green assets or eliminate high-carbon intensity assets in their portfolios or conduct green quantitative easing.

Central banks have also put forward proposals to provide financial resources for green economic activities. For instance, central banks could use their balance sheets to provide guarantees for loans to boost the financing of green investments to promote a structural shift in the economy to a low-carbon status (Dasgupta et al., 2019). Central banks could also utilize their balance sheets to ensure better access to funding schemes for commercial banks to invest in low-carbon projects or to provide loan financing to firms to invest in green projects (Aglietta, Espagne, & Fabert, 2015). These policies, however, can be controversial, as conveyed by the IMF, and would require a rethinking of the role of central banks. Appendix Table F1 summarizes the key pros and cons of various climate-related green fiscal and monetary policy instruments.

Table F1

Examples of green fiscal and monetary policy tools and potential advantages and drawbacks.

Examples of policy tools	Advantages	Disadvantages
Public investment and spending	<ul style="list-style-type: none"> *Reduces fossil fuel energy consumption (e.g. electricity generation). * More climate-friendly public goods. 	<ul style="list-style-type: none"> *Public finances may be challenged. * Transparency and accountability.
Public Private Partnerships	<ul style="list-style-type: none"> * Improves green infrastructure investment while reducing public spending. *Sharing of project risks (e.g. financial risks, timeframe). * Increases efficiency, technology and innovation expertise from the private sector. 	<ul style="list-style-type: none"> *Requires proper PPP capacity such as appropriate legal framework which is not present in many countries. *Onus is on governments to create the appropriate enabling framework. *Can result in projects becoming more expensive compared to standard procurement practices due to the higher borrowing costs faced by the private sector compared to government rates.
Carbon Pricing	<ul style="list-style-type: none"> *Leverages the market mechanism to improve resource allocation. *Revenue generating. *Internalises the externalities. 	<ul style="list-style-type: none"> *Market price set may not impact emissions. *Can be ineffective if political interference exists. *Firms may shift production to other countries. *Administrative cost of measuring firms’ emissions. *Encourages tax evasion and methods to circumvent the policy by firms.
Public Guarantee	<ul style="list-style-type: none"> *Provides an upfront ‘reward’ for low- carbon options while maximising the efficiency of using public finances. *Calibrating the guarantees on the agreed social value of climate mitigation actions (SVMA) will ensure the economic efficiency of project selection. 	<ul style="list-style-type: none"> * Public finances may be challenged.
Integrating climate-related risks analysis in central banks’ collateral frameworks	<ul style="list-style-type: none"> *Improves liquidity and reduces costs for financial institutions engaging in green projects. 	<ul style="list-style-type: none"> * Requires reorienting central banks’ objectives towards long-term sustainability rather than short-term liquidity. Only a limited number of central banks globally have an objective to promote or support sustainable economic growth.
Green QE	<ul style="list-style-type: none"> *Improves liquidity and cash flow of green investment projects. 	
Climate Change Credit Scheme (Monetary Policy)	<ul style="list-style-type: none"> *Improves financial institutions’ costs and access to funds for green projects subject to an assessment of project risks. * Sectors declared as environmental priorities can be the target of direct credit policy instruments, such as subsidised loan rates. 	<ul style="list-style-type: none"> *The emergence of trade-off relations between short-term monetary stability considerations and environmental sustainability. *Central bank’s resources may already be stretched with monetary policy and financial stability issues.

Source: Authors’ compilation based on the literature review section of the paper, including Krogstrup and Oman (2019).

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