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# The Sustainable Environment in Uruguay: The Roles of Financial Development, Natural Resources, and Trade Globalization

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As the world continues to be a globalized society, there have been variations in environmental quality, but studies including trade globalization into the environmental policy framework remain inconclusive. Therefore, employing the time series dataset of Uruguay over the period between 1980 and 2018, the main objective of this current study is to investigate the effect of trade globalization, natural resources rents, economic growth, and financial development on carbon emissions. By employing the bounds testing procedures in combination with the critical approximation *p*-values of Kripfganz and Schneider (2018), the Autoregressive Distributed Lag estimator, and spectral causality test to achieve the goal of this research. The outcomes of the bounds test confirm a long-run connection between carbon emissions and these determinants. Moreover, from the outcome of the Autoregressive Distributed Lag estimator, we observed that trade liberalization is found to exert $CO_2$ emissions in the long and short run. The economic expansion in Uruguay imposes significant pressure on the quality of the environment in the long and short run. The abundance of natural resources significantly increases environmental deterioration in the long and short run. Furthermore, we uncover that financial development does not impact environmental deterioration in Uruguay. Finally, the outcome of the spectral causality test detected that trade globalization, economic growth, and natural resources forecast carbon emissions with the exclusion of financial development. Based on the outcome, this study suggests that policies should be tailored towards international trade must be reassessed, and the restrictions placed on the exportation of polluting-intensive commodities must be reinforced.

**Keywords: carbon emissions, trade globalization, financial development, economic growth, natural resources, and spectral causality test**

# 1 INTRODUCTION

Global warming and other environmental deterioration have evolved at a rapid rate over the years, posing serious dangers to the policymakers' ambitions for sustainable development. Following industrialization, the global economy began an era of rapid growth, with the disparity between affluent and poor broadening. Simultaneously, this economic expansion brings about the dilemma of environmental deterioration, which compromises the existence of humanity (Agyekum et al., 2022). The primary causes of these concerns are significant industrial waste, widespread usage of fossil fuels, and natural resources. Likewise, the negative influence on the environment and increased environmental consciousness have consistently stimulated the interest of policymakers across the entire globe. Several nations established carbon emission mitigation and carbon peak objectives at recent climate change and environmental regulatory conferences (COP21, COP26) to attain net zero-emission and realized coordinated economic development and environment. In this sense, global leaders are attempting to enact net-zero emission policies/regulations in order to attain carbon neutrality in the next decades. Uruguay has experienced environmental catastrophes for several years, in which Uruguay is now under intense external pressure to address environmental issues.

However, the diminishing economic prospects caused by Covid-19 is a burden for the government to ensure sustainable growth while minimizing the usage of fossil-fuel energy is indeed a major problem. Natural resources are becoming scarce and diminishing daily, triggering environmental deterioration over time (Akinsola et al., 2022; Awosusi et al., 2022a; Usman and Balsalobre-Lorente, 2022). The conventional energy and product production processes are unsustainable. Awosusi et al. (2022b) emphasized the importance of energy efficiency and energy-saving measures in reducing strain on natural resources. However, Tufail et al. (2021) argue that widespread exploitation of natural resources poses serious environmental issues.

Since the rate of globalization continues to soar, the influence of globalization on climate change (particularly the trade-related globalization process) has been enormously underestimated. Several open economies have experienced significant wealth, development and enhanced lifestyle due to trade globalization. Many studies have presented different perspectives about whether trade globalization contributes to environmental degradation, which has been classified into two parts. Some studies argue in line with the "Pollution Haven Hypothesis" since advanced economies with rigorous environmental management requirements, in which the pollution or energy-intensive manufacturing operations are usually transferred to economies with less stringent regulation in respect to the environment (He et al., 2021). Proponents contend that trade activities are compromising environmental quality in emerging economies (Pata and Caglar, 2021; Murshed et al., 2022). However, as the degree of trade globalization increases, some emerging economies are being driven to compromise their environmental requirements to accommodate more international investment. Substantial amounts of energy and economic activity have both resulted in environmental deterioration in these emerging countries (Ayobamiji and Kalmaz, 2020; Balsalobre-Lorente et al., 2022; Xu et al., 2022). On the other hand, excessive utilization of natural resources contradicts the objective of sustainable development. Owing to the notion of intergenerational equity, each generation has the responsibility to maintain and select natural and cultural variety. Particularly, this present generation must be committed to protect the natural and cultural resources for the subsequent generations. Another viewpoint asserts that trade globalization can be a major determinant for combating issues of environmental degradation (Ahmed and Le, 2021), which is in line with the "Pollution Halo Hypothesis". Nations with fewer environmental restrictions can gain accessibility to modern pollution control technology through the influx of patent transfer and cross-regional factors of production, which could assist in enhancing the quality of the environment. To resolve this contentious subject, this current research considers trade globalization as one of the primary determinants influencing $CO_2$ emissions to validate this claim and provide policy recommendations.

Financial development is a crucial driver that promotes trade globalization. Based on this rationale, one of the critical factors in the present research is financial development. Financial development enhances the environmental quality of a country through advances in research and development and technical growth (Kirikkaleli and Adebayo, 2021). Adebayo et al. (2021f) agree that financial development contributes to increased economic efficiency and more opportunity to adopt modern technology to reduce environmental impact. However, several studies (such as Batool et al., 2022; Elfaki et al., 2022; Okere et al., 2022) uncovered that financial development is one of the major determinants that increase the level of $CO_2$ emissions. It was discovered that financial development is essential for the growth of the private sector, which encourages economic activity and mitigates poverty by lowering the costs spent in financial systems. By decreasing the costs of obtaining financial information, establishing contacts, and conducting transactions, new financial markets, intermediaries, and contracts can be developed. Hence, it entails the formation and extension of financial institutions, markets, and instruments; nonetheless, it has a series of negative environmental consequences. Every equipment or automobile acquired has an environmental impact since the manufacturing of these products requires energy. As a consequence of financial development, investors prefer to invest in the installations of plants and machinery that require a great deal of energy to operate, resulting in the emissions of carbon into the environment.

This research concentrates on Uruguay considering pollution in the country is a major economic and environmental concern that affects not just the nation but also the Latin American region. Recently, the mismatch between energy supply and demand has widened in Uruguay, and deteriorating environmental circumstances have posed a severe danger to the country's economy's sustainable growth objective. For instance, Extreme occurrences, such as the 2008 drought or the floods of 2014, resulted in a significant loss in the economy (Aparicio-Effen et al., 2016). Other intense occurrences have recently been recorded in 2015, in which the country's water deficit had a significant effect on the agricultural sector (Cruz et al., 2021). This drought is the longest in recent times, resulting in production issues and significant economic losses. Uruguay has become a significant player in the Latin American trade structure as a result of the removal of restrictions to international trade as part of the globalization trend. Moreover, as a small and open economy, Uruguay thrives on free trade barriers and distortions market, notably in the agriculture sector, which comprises the majority of its exports, which has had a severe impact on the nation's environmental condition (Mañay et al., 2019). Meanwhile, Uruguay has made several initiatives to reduce pollution by implementing mechanisms and tools to facilitate and significantly improve its environmental policies, particularly, the Clean Development Mechanism (CDM) and, more recently, the Nationally Appropriate Mitigation Actions (NAMAs) and REDD+ (Reducing emissions from deforestation and forest degradation).

Taking into account the abovementioned objectives as well as the existing state of the environment, the purpose of this research is to investigate the impact of natural resources, economic growth, financial development, and trade globalization on carbon emission in Uruguay. As a nation with a small population with limited domestic market opportunities, meanwhile, it ranks top in the Latin American region in terms of GDP per capita. GDP per capita doubled, reaching US$16,037 in 2018, which is its highest level (World Bank, 2022). Uruguay's natural resources continue to grow since the country is part of the world's largest food-exporting nation (together with Argentina, Brazil, and Paraguay). Uruguay is Latin America's ninth-largest carbon emitter, owing to its rapid economic growth and relatively small populace (World Bank, 2022). Thus, as the economy continues to grow, environmental degradation becomes a major concern. As a result, the research adds to the existing work in a variety of aspects. First, it was critical to analyze how the parameters used such as natural resources, economic growth, financial development, and trade globalization interacted with Uruguay's carbon emissions, as these parameters had not previously been studied concerning Uruguay, according to the authors' knowledge. It is imperative to establish a better perspective of the conflicting opinions of several studies on what could be the cause of the upsurge in carbon emissions and whether some of the parameters utilized could also facilitate in reducing the elevated level of carbon emission generated by other parameters. Second, in the context of the methodological outlook, this study considers the bounds approach by using the Kripfganz and Schneider (2018) critical value to establish the cointegrating association among the parameters used. Furthermore, the long and short-run impact of the natural resources, economic growth, financial development, and trade globalization on carbon emissions by using the Autoregressive Distributed Lag estimator. The spectral causality test, which is developed by Breitung and Candelon (2006) was employed to investigate the causal interaction between $CO_2$ emissions and these determinants. Lastly, the empirical evidence obtained in this study offers useful policy directions for implementing natural resources, financial development, trade globalization, and related economic strategies to accomplish sustainable economic and environmental development.

The remaining portions of this study are: **Section 2** contains a summary of relevant studies related to the subject matter and theoretical background. **Section 3** presents the data and methodology used in this study. **Section 4** of this study outlines the findings and discusses the empirical findings, and the fifth section discusses the conclusion.

## 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

### 2.1 Literature Review

The investigation into the association between carbon emissions, trade globalization, natural resources rents, economic growth, and financial development have been undertaken by several kinds of literature. Unfortunately, a consensus regarding the connection of trade globalization, natural resources rents, economic growth, and financial development on carbon emissions are yet to be reached due to the difference in methodology utilized, period of study, countries employed, and many more.

#### 2.1.1 Economic growth and $CO_2$ emissions

The interaction between economic growth (GDP) and carbon dioxide ($CO_2$) emissions has been conducted by extensive research in the decades. For instance, the study of Adebayo et al. (2021c) inspected the growth-emissions association in Japan utilizing the dataset ranging from 1965 to 2019. By using the FMOLS and DOLS approach, the authors confirmed a positive association between GDP and $CO_2$ emissions. In similar studies done in Japan by Adebayo (2021) using the dataset that covers between 1970 and 2015. The author uncovered a positive association between GDP and $CO_2$ emissions. In addition, He et al. (2021) inspected the interrelationship between GDP and $CO_2$ emissions for the dataset from 1990 to 2018 in the top ten energy transition economies. The CS-ARDL approach was employed and its outcome suggests that GDP contributes to the increase in $CO_2$ emissions. Adebayo et al. (2021g) found a positive interconnection between GDP and $CO_2$ emissions in South Korea for the period from 1965 to 2019. In Australia, Adebayo and Acheampong (2021) utilized the period between 1970 and 2018 to investigate the interconnection between GDP and $CO_2$ emissions and established a positive interconnection between GDP and $CO_2$ emissions using the quantile on quantile procedures. Furthermore, Yuping et al. (2021) inspected the interrelationship between GDP and $CO_2$ emissions in Argentina from 1970 to 2018 using the ARDL approach. The findings indicate a positive interconnection between GDP and $CO_2$ emissions. The study of Adebayo et al. (2021d) investigated the interrelationship between GDP and $CO_2$ emissions in Brazil. The research analysis is based on the dataset ranging from 1965 to 2019, suggesting that GDP increases $CO_2$ emissions. Later on, the research of Akadiri and Adebayo (2021), employed the NARDL approach to investigate the interconnection between GDP and $CO_2$ emissions in India from 1970 to 2018. According to the empirical results, a positive variation in GDP leads to an increase in $CO_2$ emissions. In Argentina's case, the study of Adebayo and Rjoub (2021) utilized the wavelets tools to inspect the connection between GDP and $CO_2$ emissions. The findings unveiled a positive interrelationship between GDP and $CO_2$ emissions.

### 2.1.2 Financial development and $CO_2$ Emissions

The dynamic relationship between financial development and environmental deterioration is a complex issue with differing viewpoints. According to many experts, financial development promotes environmental degradation by freeing finances for the importation of pollution-free capital and energy-efficient technologies. Numerous additional researchers contend that financial growth worsens environmental deterioration because of investor and consumer certainty to boost business and excessive energy utilization as a result of lowering investment barriers in the long term. In an ideal world, every country's financial development framework is interlinked to various methods for advancing access, depth, proficiency, institutions, and financial markets (Adebayo et al., 2021f; Huang et al., 2022). A well-structured and organized financial sector has a significant influence in accelerating economic development and, as a result, increasing a sustainable environment. For instance, Su et al. (2021) evaluated the relationship between FD and $CO_2$ emissions for the dataset from 1990 to 2018 Brazil. The empirical outcome suggests that FD contributes to the increase in $CO_2$ emissions. Elfaki et al. (2022) also found a positive interconnection between FD and $CO_2$ emissions in ASEAN + 3 economies using the dataset that covers the period from 1994 to 2018. Okere et al. (2022) undertake a study that was centered on investigating the interconnection between GDP-FD in Peru using the dataset spanning between 1971 and 2017 using the DARDL approach. The authors concluded that there is a positive interconnection between FD emissions. Conversely, the study of Usman et al. (2022) employed the dataset between 1990 and 2017 to inspect the interconnection between FD and $CO_2$ emissions and detected a negative interconnection between FD and $CO_2$ emissions. However, Batool et al. (2022) found a positive connection between FD and $CO_2$ emissions in selected developing nations in the Southern and Eastern Asian region. Furthermore, Adebayo et al. (2021b) probed into the association between financial development and emissions in Latin American nations using the dataset spanning from 1980 to 2017. The FMOLS and DOLS approach was applied and their findings indicate that financial development does not significantly influence emission in these economies. A similar outcome was confirmed in Nigeria and Argentina by Ayobamiji and Kalmaz (2020) and Adebayo et al. (2021a).

### 2.1.3 Natural Resource and $CO_2$ emissions

Over the last few decades, researchers have ignored and refused to acknowledge natural resource exploitation as a linked aspect of the environment. Furthermore, numerous scientists have successfully included this potential variable into the empirical investigation of the environment-income nexus. Given this context, it has been discovered that GDP growth promotes the progress of industrialization, which boosts natural resource exploitation. Adebayo et al. (2022) studied the relationship between natural resources abundance and $CO_2$ emissions for the dataset from 1990 to 2018 in newly industrialized countries. The MOMR approach was employed and its outcome suggests that natural resources abundance increases $CO_2$ emissions. Awosusi et al. (2022b) found a positive interconnection between natural resources abundance and $CO_2$ emissions in Colombia for the period from 1965 to 2019. Gyamfi et al. (2022) performed research that focused exclusively on the natural resources abundance-emissions interconnection in G7 economies for the period spanning from 1990 to 2016. The investigation concluded that there is a positive interconnection between natural resources abundance-emissions. Liu et al. (2022) used the MOMR approach to investigate the interrelationship between natural resources abundance-emissions in G7 nations. They established that natural resources abundance increases emissions. Majeed et al. (2022) probed into the interrelationship between natural resources abundance and $CO_2$ emissions for different income groups from 1971 to 2018 using the FMOLS and DOLS approach. The findings indicate a positive interconnection between natural resources abundance and $CO_2$ emissions in high-income nations while natural resources abundance mitigates $CO_2$ emissions in lower or middle-income nations. The research of Caglar et al. (2022) inspected the interconnection between natural resources abundance and $CO_2$ emissions in BRICS nations from 1990 to 2018. According to the empirical results, natural resources abundance to the increase of $CO_2$ emissions.

### 2.1.4 Trade Globalization and $CO_2$ emissions

Studies evaluating the effect of the trade aspect of globalization on carbon emissions are relatively few. For instance, the study of Ahmed and Le (2021) investigated the effect of trade globalization on $CO_2$ emissions in six selected ASEAN countries. The research analysis is based on the dataset ranging between 1996 and 2017, suggesting that trade globalization is a good parameter in achieving a sustainable environment for these countries since it mitigates emissions. Later on, the research of Murshed et al. (2022) for Argentina, affirms a contrary outcome that trade globalization increases the emissions level in Argentina. However, the investigation into globalization as a whole on emissions had been examined by several studies, such as; Adebayo et al. (2021e) employed the ARDL approach to inspect the interconnection between globalization and $CO_2$ emissions in South Korea from 1980 to 2018. Based on the empirical results, a positive connection is evident between globalization and $CO_2$ emissions. Adebayo and Kirikkaleli (2021) applied the wavelets tools to scrutinize the connection between globalization and $CO_2$ emissions. The findings unveiled a positive interrelationship between globalization and $CO_2$ emissions. Pata (2021) studied the interconnection between globalization and $CO_2$ emissions in BRICS countries and affirms that globalization increases $CO_2$ emissions by employing the dataset ranging between 1971 and 2016. Using the panel data of One Belt One Road (OBOR) nations, Bilal et al. (2022) investigated the association between globalization and $CO_2$ emissions using the period ranging between 1991 and 2019 and found a positive interrelationship between globalization and $CO_2$ emissions in South Asia and OBOR nations. Conversely, a negative interaction was confirmed between globalization and $CO_2$ emissions in the Southeastern, Central, and Eastern regions of Asia, Europe, and MENA.

As a result, the above-mentioned analysis of the literature identifies the important gaps that this current research seeks to address to complement the current body of knowledge. As a result, the policy conclusions of this research can be expected to enable the quest of Uruguay to achieve a sustainable environment and development while also assisting other similar developing economies in this milestone.

## 2.2 Theoretical Framework

The increasing economic expansion in Uruguay is fueled by considerable use of energy and complimented by the rapid cross-border flow of goods and services via globalization. Along with these factors, the availability of natural resources provides Uruguay with leverage to stimulate economic expansion. With the surge in economic growth in Uruguay, the financial sector will also improve, over time.

Unfortunately, an energy-driven economy such as the Uruguay economy continues to have a negative environmental externality in the form of carbon emissions. Demand for energy in the industrial sector continues to increase as a result of globalization, and the current innovations in the energy sector were insufficient to minimize this level of emissions. Underdeveloped financial institutions offer finance for economic operations (low-cost borrowing to families and enterprises), which encourages energy demand while simultaneously degrading the environment (Kirikkaleli et al., 2022). A robust financial sector can help to improve environmental sustainability by allocating more resources towards clean energy and mobilizing the money needed to invest in environmentally friendly infrastructure and assure environmental sustainability (Batool et al., 2022).

Furthermore, it should be noted that Uruguay is rich in natural resources, and the country's developmental rate may not be sustainable. As a result, the country may have to depend on its natural resource reserves to meet its energy needs. The majority of these natural resources contain the composition of molecular hydrocarbon, and when consumed, they oxidized, resulting in $CO_2$ emissions (Ma et al., 2019). As a result of the availability of natural resources and the growth, trajectory worsens environmental quality.

# 3 DATA AND METHODOLOGY

## 3.1 Data

This study evaluates the impact of natural resources, economic growth, financial development, and trade globalization on carbon emission in Uruguay. This present study uses a dataset ranging from 1980 to 2018. However, the unavailability of data hampered the period of study and sample size. For this study, carbon emissions are the endogenous variable, and these variables: natural resources abundance, economic growth, financial development, and trade globalization are the exogenous variables. All the variables of the investigation are transformed into a natural log to reduce heteroscedasticity. However, the sources, metrics for the variable of concern are presented in **Table 1**.

The model for this study is constructed as follows:

$$CO_2 = f\,(GDP_t,\ NRR_t,\ TGLO_t,\ FD_t,\ ) \tag{1}$$

$$CO_2 = \beta_0 + \beta_1 GDP_t + \beta_2 NRR_t + \beta_3 TGLO_t + \beta_4 FD_t + \varepsilon_t \tag{2}$$

Where: $CO_2$, GDP, NRR, FD, TGLO, and $\varepsilon$ denote carbon emissions, economic growth, natural resources, financial development, trade globalization, and the error term, t indicates the period of consideration (1980–2018).

The trade-off between GDP and the environment has been established in energy literature. Therefore, we anticipated that the coefficient between $CO_2$ emissions and GDP is positive, i.e., ($\beta_1 = \frac{\delta CO_2}{\delta GDP} > 0$). Resource extraction accelerates economic growth and degrades environmental quality. As a result, it is anticipated that natural resource abundance will have a negative impact on environmental quality. i.e., ($\beta_2 = \frac{\delta CO_2}{\delta NRR} > 0$). Trade globalization considers the participation of Uruguay in terms of foreign trade. When trade globalization has a high (low) value, it indicates that Uruguay's participation in trade with other nations is at a higher (lower) degree. When $\beta_3$ has a positive sign. i.e., ($\beta_3 = \frac{\delta CO_2}{\delta TGLO} > 0$), it indicates that trade globalization is expected to develop pollution-intensive sectors, thereby degrading the environment in Uruguay. Conversely, having a negative sign for the coefficient of trade globalization. i.e., ($\beta_3 = \frac{\delta CO_2}{\delta TGLO} < 0$), suggests that globalization through the conduit of trade globalization is expected to improve the quality of the environment. However, certain research, such as Usman et al. (2022) conclude that financial development has a positive connection with $CO_2$ emissions. They argue that financial development encourages research & development as well as green energy initiatives thereby stimulating innovation and, as a result, contributes to the enhance the quality of the environment. .i.e., ($\beta_4 = \frac{\delta CO_2}{\delta FD} < 0$), Some research, however, such as Pata (2018), Batool et al. (2022), and Adebayo et al. (2021b), argue that financial development increases the deterioration of the environment. They asserted that the financial sector is usually financially motivated rather than environmental consciousness and that convenient availability of financial services stimulates the usage of the resource. As a result, financial development is expected to degrade the environment if it is not eco-friendly. i.e., ($\beta_4 = \frac{\delta CO_2}{\delta FD} > 0$).

## 3.2 Methodology

Pesaran et al. (2001) developed the ARDL bounds testing approach to investigate long-run interconnectivity among variables having a mixed integration order I (1) or I (0) but

**TABLE 1** | Description of variables.

| Variables | Metric | Sources |
|---|---|---|
| Carbon emissions | $CO_2$ emissions per capita | BP |
| Economic growth | GDP per capital | WDI |
| Natural resources abundance | Natural resources rents | WDI |
| Financial development | Financial development index | IMF |
| Trade globalization | Globalization index measured by trade | KOF |

not I (2). When utilizing this method, the dependent variable (i.e., $CO_2$) needs to be I (1) (Pesaran et al., 2001). The benefit of this approach are as follows: (1) it is suitable for small sample size (Kirikkaleli et al., 2021); (2) it accommodates a mixed order of integration during analysis (Kalmaz and Awosusi, 2022); (3) endogeneity issues are solved.

The previous unrestricted ECM is used to evaluate cointegration.

$$\begin{aligned}\Delta CO_{2_t} = {} & \omega_0 + \sum_{l=1}^{p}\omega_1 \Delta CO_{2_{t-1}} + \sum_{i=1}^{p}\omega_2 \Delta GDP_{t-1} + \sum_{i=1}^{p}\omega_3 NRR_{t-1} \\ & + \sum_{i=1}^{p}\omega_4 \Delta TGLO_{t-1} + \sum_{i=1}^{p}\omega_5 \Delta FD_{t-1} + \varphi_1 CO_{2_{t-1}} \\ & + \varphi_2 GDP_{t-1} + \varphi_3 NRR_{t-1} + \varphi_4 TGLO_{t-1} + \varphi_5 FD_{t-1} \\ & + \epsilon_t \end{aligned} \tag{3}$$

Where: $\Delta$, $\omega_i$ $(i = 1, \ldots .5)$, an d $\varphi_i$ $(i = 1 \ldots .5)$ indicate the difference operator, short and long term coefficients, $\epsilon$ denotes the error term and $\omega_0$ indicates intercept. By including the ECM into the ARDL, **Eq. 3** is transformed into **Eq. 4**:

$$\begin{aligned}CO_{2_t} = {} & \omega_0 + \sum_{l=1}^{p}\omega_1 \Delta CO_{2_{t-1}} + \sum_{i=1}^{p}\omega_2 \Delta GDP_{t-1} + \sum_{i=1}^{p}\omega_3 NRR_{t-1} \\ & + \sum_{i=1}^{p}\omega_4 \Delta TGLO_{t-1} + \sum_{i=1}^{p}\omega_5 \Delta FD_{t-1} + \varphi_1 CO_{2_{t-1}} \\ & + \varphi_2 GDP_{t-1} + \varphi_3 NRR_{t-1} + \varphi_4 TGLO_{t-1} + \varphi_5 FD_{t-1} \\ & + \alpha ECT_{t-1} + \epsilon_t \end{aligned} \tag{4}$$

Where: the degree of short-run modification to achieve long-term equilibrium and ECT symbolizes the error correction term. This coefficient's predicted sign ($\alpha$) is, as expected, significant and negative. The ARDL approach was used to investigate the dynamic connection between $CO_2$ emissions and its determinants after discovering the cointegration connection in **Eq. 4**.

## 3.3 Frequency Domain Causality Test

However, when the coefficients of the interaction are disclosed, the direction of the interaction amongst parameters is unpredictable, i.e., the causal relationship between $CO_2$ and GDP or vice versa. But, such an analysis could not be pursued using non-linear analysis. As a result, the frequency domain causality technique was used in this work, which is an innovation of Breitung and Candelon (2006). The spectral BC causality technique is another name for this test. In comparison to a causality time-domain method that solely shows time series variability. For simplicity, it can identify causal interaction between two series at long, medium, and short term. This test uncovers the magnitude of frequency-domain assessment, which may be employed to discover nonlinearity and causal cycles at both high and low frequencies. One of the major strengths of this approach is the ability to uncover causal connections between sets at different frequencies. The approach is centered on the reconstructed Vector Autoregressive (VAR) interaction between x and y, which is written as:

**TABLE 2** | Descriptive statistics.

| | $CO_2$ | TGLO | FD | NRR | GDP |
|---|---|---|---|---|---|
| Mean | 1.6916 | 42.080 | 0.1748 | 0.7923 | 9292.1 |
| Median | 1.6753 | 39.702 | 0.1755 | 0.5477 | 8449.2 |
| Maximum | 2.5430 | 57.927 | 0.3023 | 2.0323 | 14617.4 |
| Minimum | 1.0441 | 31.708 | 0.0932 | 0.1758 | 5825.7 |
| Std. Dev | 0.3748 | 7.5718 | 0.0481 | 0.5331 | 2699.8 |
| Skewness | 0.3528 | 0.4469 | 0.3955 | 0.7828 | 0.7169 |
| Kurtosis | 2.6193 | 2.0036 | 2.8148 | 2.1797 | 2.2491 |
| Jarque-Bera | 1.0445 | 2.9116 | 1.0728 | 1.3762 | 4.2577 |
| Probability | 0.5931 | 0.2332 | 0.5848 | 0.49790 | 0.1189 |
| Obs | 39 | 39 | 39 | 39 | 39 |

$$x_t = \theta_1 x_{t-1} + \ldots . + \theta_1 x_{t-1} + \beta_1 y_{t-1} + \ldots + \beta_l y_{t-1} + \varepsilon_t \tag{5}$$

To select the optimal lag ($l$), the study used the Akaike Information Criterion (AIC). The null hypothesis is stated as:

$$H_0\colon\ R(\omega)\beta = 0 \tag{6}$$

The vector that connects the y coefficients is denoted as $\beta$:

$$R(\omega) = \frac{\cos(\omega)\cos(2\omega)\ldots .\cos(l\omega)}{\sin(\omega)\sin(2\omega)\ldots .\sin(l\omega)} \tag{7}$$

t = $\frac{2\pi}{\omega}$, which indicates t as period and is connected to the frequency $\omega$.

## 4 FINDINGS AND DISCUSSIONS

The descriptive nature of the dataset which includes the normality of the data used must be uncovered before the actual assessment (such as unit root, cointegration, and other

**TABLE 3** | Unit-roots outcome.

| | ADF | | PP | |
|---|---|---|---|---|
| | I (0) | I (1) | I (0) | I (1) |
| $CO_2$ | −3.499 | −5.260[a] | −3.539 | −5.820[a] |
| GDP | −4.417[a] | −3.326[b] | −3.363[b] | −3.404[b] |
| TGLO | −2.191 | −5.604[a] | −2.320 | −5.605[a] |
| NRR | −1.953 | −5.687[a] | −1.991 | −5.731[a] |
| FD | −1.230 | −6.696[a] | −1.237 | −6.732[a] |

[a]*depicts significance level of 0.01.*
[b]*depicts significance level of 0.10.*

modelling techniques) is undertaken. However, the descriptive natures of the dataset of concern are presented in **Table 2**. The findings show that the mean values of $CO_2$, TGLO, FD, NRR, and GDP are within the normal range, indicating that there are no outliers in the dataset. However, the computed standard deviation values suggest that there is an appropriate degree of variance in the data for all parameters under consideration. Moreover, the computed skewness of all parameters used is within the range of −1 to +1. For the Kurtosis, the computed value is less than three for all parameters under consideration. This indicates that all the parameters used are normally distributed, which is corroborated by the Jarque-Bera value and probability. Thus, the dataset has an appropriate degree of normality and can be used for further research and policy decision.

After the normality testing *via* descriptive statistical evaluation and before the implementation of cointegration, unit root tests should be used to assess the parameters' nature of stationarity. This stage is vital since it not only aids in determining the nature of stationarity of the parameter used but, it also serves in deciding on an appropriate test for subsequent analysis. We used ADF and PP unit root testing in this current research. **Table 3** shows the outcome, which reveals that all of the parameters under consideration are stationary at first difference except for GDP wherein it is stationary at level. As a result, the data is best suited for co-integration as well as the ARDL estimator.

The unit root evaluation provides information on the presence of co-integration in the dataset. As a result, we conducted the bounds co-integration test using the critical value of Kripfganz and Schneider (2018) to determine whether or not there is a co-integration relationship between the parameters used. **Table 4** displays the findings of the co-integration analysis. Having compared the computed F and T statistics of the bound testing procedures with the critical values of Kripfganz and Schneider (2018). The null hypothesis of no cointegration is rejected at 1 and 5% significant levels for F-statistics and T-statistics, respectively. One can demonstrate the presence of a long-run relationship (co-integration) among the variables of interest. Similarly, this technique has significant implications for long-term assessments. Thus, we confirmed long-run cointegration amongst parameters of research. As previously noted, the study utilizes the ARDL approach to uncover the findings. As a result, the next part focuses on discussing and presenting the outcomes of this approach.

The emphasis of this current study is to examine whether trade globalization contributes to $CO_2$ emissions. In addition, this current research tends to probe into the impact of economic growth, natural resources, and financial development in Uruguay. Bearing in mind that the major goal of this current research and the findings are presented in **Table 5**, we uncover a positive interaction of trade globalization with $CO_2$ emissions. The finding reveals that increasing the level of trade globalization by 1% will contribute to the level of $CO_2$ emission by 0.497 and 0.289% in long and short, respectively. Meanwhile, trade globalization promotes growth in the economy, whereas, its effects on the environment are unfavorable. As a result, the tradeoff between trade globalization and the environment should be win-win rather than one-sided. Since one-way situation poses serious issues on the environment in the long term. Furthermore, natural resources can have a tremendous impact on economic expansion and climate change. As a result, assessing the contribution of natural resources to the environment is critical. Only a few research have been conducted on this phenomenon in the past. Thus, generalizations of outcomes from those research are limited. As a result, we tend to develop an investigation on natural resources and the environment by assessing the effect of natural resources in terms of $CO_2$ emissions in Uruguay in this current study. The ARDL estimates suggest that natural resources positively influence carbon emissions in Uruguay. As seen in **Table 5**, a 1% increase in natural resources will result in an increase in $CO_2$ emissions by 0.160% in the long term and 0.129% in the short term.

Also, the role of economic growth will be examined, based on the findings in **Table 5**, economic growth has a significant impact on Uruguay's $CO_2$ emissions. According to the estimates from the ARDL approach, a 1% increase in the economic expansion in Uruguay increases the country's carbon emissions by 2.249% in the long term and 1.766% in the short term. Finally, considering the significance of financial development to an economy, we have addressed the effect of financial development in terms of carbon emissions. The findings indicate that foreign direct investment does not influence Uruguay's carbon emission in both the long and short term.

**TABLE 4** | Bounds testing outcomes.

| Model | F-statistics | T-statistics | Ho | Ha |
|---|---|---|---|---|
| *$CO_2$ = GDP, TGLO, NRR, FD* | 5.925[a] | −4.264[b] | No cointegration | Cointegration |

[a]*1% levels of significance.*
[b]*5% levels of significance.*

**TABLE 5 |** ARDL estimator result.

| Regressors | Coefficient | Std. error | t-statistic | Prob. |
|---|---|---|---|---|
| **Long-run outcomes** | | | | |
| GDP | 2.249[b] | 0.920 | 2.443 | 0.022 |
| TGLO | 0.497[c] | 0.250 | 1.988 | 0.058 |
| NRR | 0.160[c] | 0.090 | 1.773 | 0.089 |
| FD | −0.173 | 0.151 | −1.140 | 0.265 |
| Short-run Outcomes | | | | |
| $\Delta$GDP | 1.766[a] | 0.483 | 3.655 | 0.001 |
| $\Delta$TGLO | 0.289[a] | 0.058 | 4.924 | 0.000 |
| $\Delta$NRR | 0.129[b] | 0.055 | 2.312 | 0.030 |
| $\Delta$FD | −0.173 | 0.127 | −1.359 | 0.187 |
| C | −4.162[a] | 1.251 | −3.325 | 0.002 |
| ECT (−1) | −0.660[a] | 0.113 | −5.813 | 0.000 |
| R-squared | 0.88 | — | — | — |
| Adjusted R-squared | 0.87 | | | |

*[a]Stands for 1% level of significance.*
*[b]Stands for 5% level of significance.*
*[c]Stands for 10% level of significance.*
*$\Delta$ denote short-run.*

The results of the diagnostic tests show that our model is devoid of the following issues: heteroscedasticity, non-normality, misspecification, and serial correlation as presented in **Table 6**. **Figure 1** also displays the plots of the CUSUM and CUSUMSQ, in which they are within the 5% significance level, indicating the model's stability. Based on all diagnostic evaluations carried out we conclude that the estimates of the ARDL approach can be used in formulating robust and reliable policy initiatives.

**TABLE 6 |** Model diagnostic tests outcomes.

| Diagnostic tests | $X^2$ (*p*-Values) | Conclusion |
|---|---|---|
| Normality Test | 0.605 (0.739) | Residuals are distributed Normally |
| Ramsey RESET Test | 1.220 (0.235) | There is no issue of misspecification |
| Breusch-Pagan-Godfrey | 0.719 (0.718) | There is no heteroskedasticity issue |
| serial correlation LM | 2.345 (0.111) | There is no serial correlation issue |

Furthermore, having established the impact of each parameter on carbon emissions, this current study improves the robustness of the empirical results by utilizing the spectral causality test developed by Breitung and Candelon (2006) to investigate the causal interaction between $CO_2$ emissions and determinants. This technique has gradually attracted considerable attention since it has been used by numerous scholars in the energy and environment literature, i.e., (Alola et al., 2021; Su et al., 2021; Xu et al., 2022). This test can generate long, medium, and short-term findings depending on different frequencies. **Figures 2A–D** showcases the estimated results. In an attempt to determine the causality relationship from trade globalization to $CO_2$ emissions. We discovered strong evidence to refute the null hypothesis that trade globalization does not granger causes $CO_2$ emissions in the long run based on **Figure 2A**. As a result, trade globalization is a strong predictor of Uruguay's $CO_2$ emissions in the long run. In addition, we discovered evidence to refute the null hypothesis of no causal relationship from natural resources to $CO_2$ emissions in the medium and long run. As highlighted in **Figure 2B**, we can suggest that there is a causal relationship from natural resources to $CO_2$ emissions in the long and medium run in Uruguay. As a result, natural resource is a significant predictor of Uruguay's $CO_2$ emissions in the long and medium run. In addition, the outcome of the spectral causality test in **Figure 2C** affirmed that we reject the null hypothesis of no causal relationship from economic growth to $CO_2$ emissions in the long, medium, and short run. Thus, economic growth is a significant predictor of Uruguay's $CO_2$ emissions in the long, medium, short term. Finally, for financial development, as seen in **Figure 2D**, we fail to

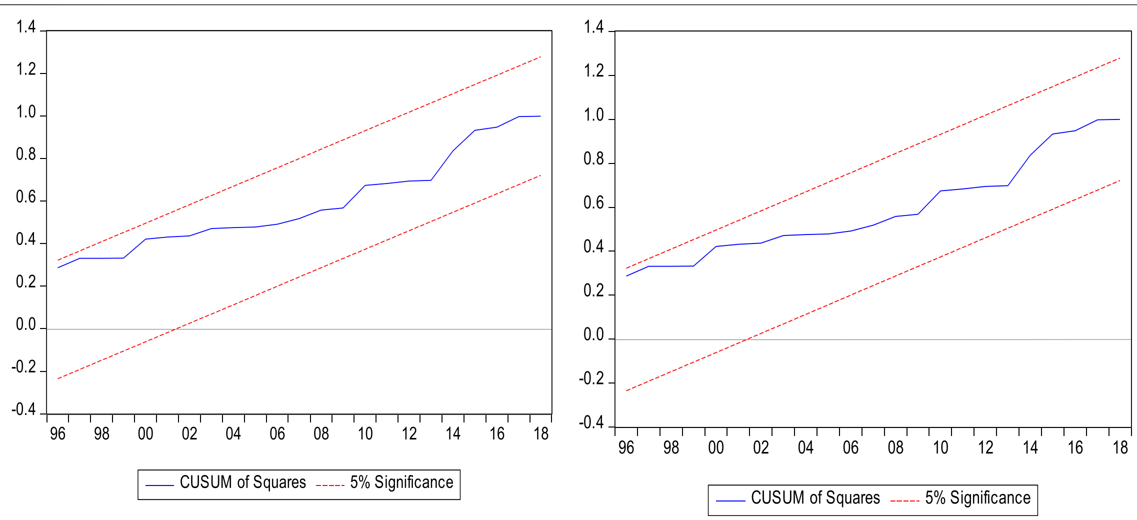


**FIGURE 1 |** Stability test.

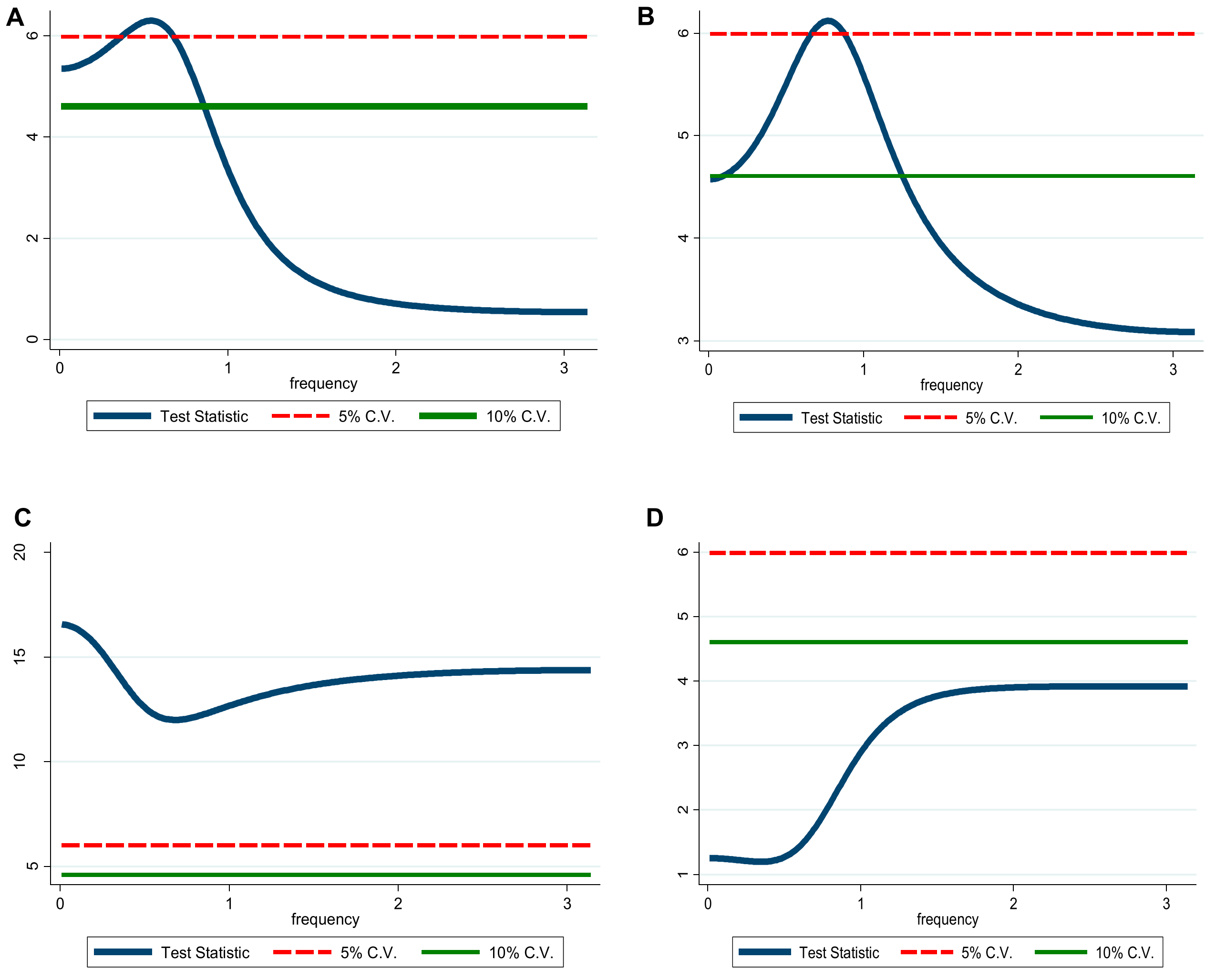


**FIGURE 2 |** Spectral BC causality from TGLO to $CO_2$. **(A)** Spectral BC causality from NRR to $CO_2$. **(B)** Spectral BC causality from GDP to CO2. **(C)** Spectral BC causality from FD to CO2 **(D)**.

reject the null hypothesis of no causal relationship from financial development to $CO_2$ emissions.

## 4.1 Discussion of Findings

The outcomes of this current study exhibit a positive relationship between trade globalization and carbon emissions. This research indicates that the policies towards trade globalization are anticipated to have a negative impact on Uruguay's environment. It has become obvious that trade globalization is a major determinant that contributes to environmental degradation. This conclusion is reinforced by the notion that Uruguay is primarily reliant on fossil fuels, implying that the country maintains its competitive advantage in the manufacture of pollution-intensive commodities through the usage of fossil fuels. Thus, Uruguay's determination to progressively integrate its economy could improve and encourages the growth of polluting industries, causing the country a net exporter of these goods, thereby contributing to the increase in carbon emissions in major sectors like the agricultural, manufacturing, and energy sectors. Our outcome aligns with the findings of Murshed et al. (2022) who conclude that trade globalization degrades the environment in Argentina. However, the study of Ahmed and Le (2021) established a contrary viewpoint by establishing that trade globalization mitigates $CO_2$ emissions in six selected ASEAN countries. As a result of the findings, a fresh debate regarding policy formation are been opened up based on the perspective of developing countries.

Additionally, natural resource policies serve as a critical bedrock for managing resources, usage, and conservation. This current research emphasized the impact of natural resources in terms of $CO_2$ emissions concerning the challenges of climate change in the country as well as the depletion of natural resources. As a result, we expect the insights of this study can serve as a baseline for developing regulations linked to natural resource and environmental management. The current study's outcomes show that natural resources impede the quality of the environment in

Uruguay, wherein $CO_2$ emission levels surge. This result is consistent with the previous remark that the revenue from the natural resource is primarily diverted towards further production pathways or exploitations of natural resources that could contribute to subsequent environmental degradation. This outcome agrees with Adebayo et al. (2022) whose investigation was focused on the dataset of newly industrialized countries and found that natural resources increase $CO_2$ emissions. Awosusi et al. (2022b) in Colombia, Caglar et al. (2022) in BRICS economies, and Liu et al. (2022) in G7 economies concluded that natural resources degrade the environment.

This current study discovered that a rise in Uruguay's economic growth contributes to an increase in the country's $CO_2$ emissions. It indicates that the trajectory in both the long and short term suggests that Uruguay tends to enjoy and accept more economic benefits at the expense of environmental quality. This finding is predictable considering that the most of developing economies, like Uruguay, are experiencing rapid economic growth in the last decade while also simultaneously increasing the overall $CO_{2e}$ emissions levels. The excessive dependence on the utilization of fossil fuels to satisfy the requirement of the business and residential sectors raises $CO_2$ emissions. Under such circumstances, the implications of Uruguay's undesirable environmental ramifications of economic development are validated. This current study's results are consistent with those of Adebayo et al. (2021c), who discovered that GDP increases the $CO_2$ emission level in Japan. He et al. (2021) conducted research in the top ten energy transition economies and discovered that GDP has a positive impact on $CO_2$ emissions. Adebayo et al. (2021g), Adebayo and Rjoub (2021), and Akadiri and Adebayo (2021) discovered a positive connection between GDP and $CO_2$ emissions in South Korea, Argentina, and India, respectively.

Furthermore, we discovered that financial development does not impact environmental deterioration in Uruguay. Given that developing countries like Uruguay, have a financial sector, that is, still undeveloped, borrowed monies are intended to be invested in polluting industries without the threat of getting penalized under environmental protection regulations. Moreover, considering that the developing countries in the Latin American region depend heavily on the importation of fossil fuels, the additional financial resources are unlikely to necessitate the investment in environmentally friendly industrial operations. This current study's results agree with those of Ayobamiji and Kalmaz, (2020), who detected that financial development has no significant impact on the level of $CO_2$ emission in Nigeria. Adebayo et al. (2021a)'s research in Argentina detected that financial development has no significant impact on $CO_2$ emissions. Also, the finding of Adebayo et al. (2021b) for Latin American nations indicates that financial development does not significantly influence $CO_2$ emission in these economies. However, this outcome contradicts the recent studies of Su et al. (2021), who detected a negative interconnection between financial development and $CO_2$ emissions in Brazil, and Batool et al. (2022) found a positive connection between financial development and $CO_2$ emissions in a selected developing nation in Southern and Eastern Asian region.

## 5 CONCLUSION AND POLICY RECOMMENDATION

### 5.1 Conclusion

This current research probes into whether trade globalization affects carbon emissions. Moreover, we also ascertain the impact of economic growth, financial development, and natural resources on $CO_2$ emissions in Uruguay. The empirical assessment was conducted with bounds testing procedures, the ARDL approach, and the spectral causality test, which offers precise insights. Premised on our evaluation, the bounds testing procedures, as well as the critical values of Kripfganz and Schneider (2018), confirm that there is a cointegrating interaction between $CO_2$ emissions and these determinants (trade globalization, economic growth, financial development, and natural resources). Moreover, from the outcome of the ARDL approach, we observed that trade globalization, economic growth, natural resources contribute to $CO_2$ emissions in Uruguay. Furthermore, we uncover that financial development does not impact $CO_2$ emissions in Uruguay. The outcome of the spectral causality test detected that trade globalization, economic growth, and natural resources forecast $CO_2$ emissions with the exclusion of financial development. Taking into account the outcomes, the research made certain policy recommendations.

### 5.2 Policy Recommendation

The following policy ramification is made based on the empirical outcome of this present study: the adverse effect of trade globalization on the environment suggests that policies should be tailored towards international trade must be reassessed, and the restrictions placed on the exportation of polluting-intensive commodities must be reinforced. Such an effort would restrain the growth of polluting industries while promoting the growth of comparatively cleaner sectors. As a result, carbon emissions from the agricultural, manufacturing, and industrial sectors can be greatly decreased.

Secondly, the empirical findings indicate that natural resources degrade the environment. Considering this finding, there is a need for the government to mitigate the overexploitation of natural resources, which can be achieved through tightening and strengthening the prevailing natural resource tax legislation. Furthermore, green tax guidelines that are both sustainable and environmentally beneficial should be implemented to encourage green investment.

Next, in light of the impact of economic growth on $CO_2$ emission, the government must align its present economic growth policies towards the green initiatives so that subsequent economic expansion in Uruguay does not undermine the quality of the environment. This emphasizes the need for Uruguay to experience a sustainable energy transition, in which the country's energy demand is satisfied by generating energy through renewable energy sources.

The empirical outcome concludes that financial development does not impact $CO_2$ emissions. From this perspective, Uruguay should exert effort towards ensuring that the financial sector achieves the goal of a sustainable environment. As a consequence, initiatives to implement green financing techniques should be prioritized; thereby ensuring that the support for green investments initiatives is critical. Likewise, we proposed that the government of Uruguay should raise funds that support programs aimed at combating global warming; therefore, climate finance is essential to enhance the environmental outcomes associated with financial development.

Despite the study's considerable contribution to environmental literature, particularly in Uruguay. Meanwhile, this present study has several drawbacks. These drawbacks stem from the study's utilization of only a few parameters. Future research may incorporate more parameters and investigate their impact on various environmental metrics. Also, upcoming research should undertake this connection with the framework of the Environmental Kuznets curve or Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT). Given the unavailable datasets, it would be desirable to address these constraints in the future study. Upcoming studies can employ a non-linear approach to determine the effect of the studied variables.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

## AUTHOR CONTRIBUTIONS

AAA: Conceptualization, data collection, formal analysis, and methodology, NX: Writing the original manuscript, writing—review and editing. MoA: Reviewed the paper and made corrections. HR and MeA: Writing—review and editing, validation. SU: Writing original manuscript and data collection. SSA and DK: Writing—review and editing, administration.

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