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Research article

Fueling economies through credit and industrial activities. A way of financing sustainable economic development in Brazil

Larissa M. Batrancea[1,*], Anca Nichita[2], Horia Tulai[1], Mircea-Iosif Rus[3] and Ema Speranta Masca[4]

[1] Department of Business, Babes-Bolyai University, Cluj-Napoca, Romania
[2] Faculty of Economics, "1 Decembrie 1918" University of Alba Iulia, Alba Iulia, Romania
[3] National Institute for Research and Development in Constructions, Urbanism and Sustainable Spatial Development "URBAN INCERC", Cluj-Napoca, Romania
[4] "George Emil Palade" University of Medicine, Pharmacy, Sciences and Technology, Targu Mures, Romania

*** Correspondence:** Email: larissa.batrancea@ubbcluj.ro.

Abstract: As an emerging country preoccupied with preserving its resources for the future, Brazil aims to find the right balance between economic advancement and sustainability goals. In this context, we tackled the link between sustainable economic development and macroeconomic indicators related to domestic credit granted to the private sector, CO_2 emissions from industries, and annual inflation rate. By means of time series data analysis run for the period 1996–2022 via three estimation methods (i.e., least squares, fully modified least squares, dynamic least squares), we found that annual GDP growth rate, control of corruption, and rule of law (as proxies for sustainable economic development) are significantly impacted by GDP growth rate and emissions. Therefore, access to financial resources and intensive industrial activities yielding emissions trigger economic growth, tend to strengthen control of corruption and the rule of law. Additionally, policy implications and future research directions are addressed.

Keywords: economic growth; control of corruption; rule of law; greenhouse gas emissions; inflation; emerging market

JEL Codes: G21, G28, O44, Q56

1. Introduction

At the global level, economic and environmental systems are challenged because of two reasons. From an economic perspective, there is a high demand for financial resources across all economies. From an environmental perspective, there is a rise in climate challenges and an overall climate imbalance. These reasons become prevalent, especially in developing countries, which usually are challenged to find a balance between population growth – entailing substantial financial resources to secure living conditions, wellbeing – and climatic hazards. For that matter, in the last quarter of the century, developing countries have registered the largest ratio of population growth compared to other countries. Moreover, these nations host 83% more people than in prior years (United Nations Trade and Development, 2022). In the context of climate change risks, International Finance Corporation (2018) estimates that failure to properly manage climate change triggers a loss of 1.8% in the global GDP.

As an emerging market (Barbosa et al., 2017; Chivvis & Geaghan-Breiner, 2023; De Mello, 2011; Lynn et al., 2011), Brazil produces the sixth largest quantity of greenhouse gas emissions (GHG) in the world (Emissions Database for Global Atmospheric Research, 2023). Yet, the country adopted the National Climate Change Policy in 2009 and is actively committed to the efforts of the Paris Climate Agreement (Asher, 2018), which entails important financial resources (Thwaites et al., 2015). Furthermore, while discussing the carbon profile of Brazil, Timperley (2018) observes that the country is committed to reduce 37% of the GHG emissions by 2025 compared to 2005 levels.

The country has been favoring neo-industrialization through the policy called New Industry Brazil, which is grounded on sustainability and innovation (Lacerda, 2024) and aims to increase economic development by the year 2033.

According to the literature, some researchers have examined the impact of CO_2 emissions on economic growth (Aye et al., 2017; Osadume & University, 2021; Rigas & Kounetas, 2024), while others have investigated how indicators of economic growth determine the levels of CO_2 emissions (Karedla et al., 2021; Maâlej & Cabagnols, 2021; Minh et al., 2023). Studies on the link between CO_2 emissions and economic growth in emerging and developing countries from Latin America (including Brazil) are of particular interest since these two variables have been diverging in the last period (Singh, 2024; Morley, 2000). Namely, their relationship has been gradually changing due to clean energy investments and improvements in energy intensity, which is achieved mainly by developed nations. In this context, after studying the 3E relationship between energy, economics, and environment for 31 countries, González-Álvarez and Montañés (2023) suggest that advanced economies have managed to decouple economic growth from CO_2 emissions. In the same vein, authors have reported on notable advances registered by emerging economies, though to a lesser extent. Moreover, Balza et al. (2024) analyzed data from 136 countries during the period 1970–2020 and noted that it is possible to disentangle economic growth from GHG even for countries positioned lower on the development ranking.

Amid challenges stemming from the economic and environmental systems, countries worldwide need balanced economic development, which depends on how economic growth is achieved and at what pace since "economic growth is a marathon, not a sprint" (Ventura, 2024). In this sense, we believe that sustainable economic development (Wang, 1996) depends on the GDP growth rate and is closely linked to the control of corruption (Zhang et al., 2023). Generally, countries where authorities manage to efficiently deter the excessive use of public power for private gain can streamline their economies, establish a well-functioning business environment that constantly attracts new investors, have civil servants working for citizens' well-being and improve their levels of economic development

(Gray & Kaufmann, 1998; Rose-Ackerman, 1997; Spyromitros & Panagiotidis, 2022). Moreover, a stable level of economic development is supported by a strong rule of law, with authorities being capable of protecting civil rights and private property, enforcing legal precepts, and sanctioning non-compliance when applicable (Dam, 2006).

We investigate the extent to which sustainable economic development in Brazil is influenced by macroeconomic indicators such as domestic credit granted to private sector, CO_2 emissions from manufacturing industries and construction, and annual inflation rate in the long run. For the purpose of our study, sustainable economic development is proxied by annual GDP growth rate, control of corruption, and rule of law.

The novelty of the study lies in our investigation of the relationship between sustainable economic development and the chosen macroeconomic indicators by means of time series data analysis across the period 1996–2022. The methodology comprises three econometric models estimated via least squares, fully modified least squares, and dynamic least squares.

The remainder of the manuscript comprises the following. In Section 2, we detail relevant studies from the literature addressing factors that influence economic development. In Section 3, we present the research methodology and variables of interest. Section 4 comprises the empirical results yielded by the time series data analysis. Section 5 entails concluding remarks and avenues for future research.

2. Literature review

We deem that a country's sustainable economic development is determined by the annual GDP growth rate, the way public authorities control corruption, and how they implement the rule of law (Bufford, 2006). In the long run, economies prosper and develop when potential investors (both corporate and individuals) observe that state authorities protect human rights (i.e., cultural, economic, social), secure contract enforcement, efficiently enact legal precepts, streamline business environments, and make sure that public power is not used for private gain.

In the following paragraphs, we delve into relevant studies from the literature that entail determinants of economic growth, control of corruption and rule of law, and we advance our three research hypotheses.

Determinants for economic growth

Economic growth is the precursor of economic development and it captures a rise in the production of goods and services during one period when compared to a prior period. Generally, economic growth can be measured by the gross domestic product (GDP) or by the annual GDP growth rate. Researchers have extensively documented the factors that drive economic growth, among which capital, CO_2 emissions, and inflation play an important role.

First and foremost, capital in general and capital investment, in particular, are central for starting a business endeavor and expanding it once it has been established as a well-functioning entity (Barro, 1999; Mbate, 2013; Samad & Masih, 2016). Capital finances the purchasing of assets (including production facilities, inventory, and raw materials), research and development of product and services, payment of labor force, business promotion, debt refinancing, etc. Starting with these necessities, start-up companies from both developed and developing nations need domestic credit from the banking system, especially in their initial stages (Gizaw, Getachew, & Mancha, 2024). If commercial banks manifest reluctance toward financing new businesses, limited access to credit substantially tends to

mitigate entrepreneurial initiatives and hinder long-term economic growth. For instance, based on data from 1994 until 2018, Asravor et al. (2023) examined the causal link between domestic debt and economic growth in Ghana and found a positive impact of debt. In Brazil, financial institutions such as Banco do Brazil and Brazilian Development Bank (BNDES) have incorporated sustainable development as one of their goals by driving credit allocation and assuring green bonds.

Second, research has elicited a relationship between CO_2 emissions and economic growth (Acheampong, 2018). In this sense, using data from eight South-Eastern European countries spanning the period 1995–2019, Mitić et al. (2023) reported a bidirectional Granger causality between CO_2 emissions, GDP, and employment. Azam et al. (2016) examined empirical data from China, India, Japan, and the USA during the period 1971–2013 by means of fully modified least squares. Interestingly enough, group analyses show a negative impact of emissions, while country-wise analyses yield a positive impact of CO_2.

Third, inflation can also influence economic growth (Bazaluk et al., 2024), with studies reporting a negative impact (De Gregorio, 1992). As growing inflation manifests within an economy, the national currency loses its purchasing power and consumers reduce their demand, which causes businesses to produce less, thus slowing economic growth. Ekinci et al. (2020) analyzed whether a certain inflation level conditions economic growth. Empirical results indicate that economic growth is mitigated when inflation exceeds the 4.182% threshold in emerging countries. Below this level, the connection between the two variables is not significant.

Determinants for control of corruption

Within the public sector, corruption is generally defined as the use of private power for private gain and can be found under various forms (e.g., bribery, conflict of interest, embezzlement, extortion, money laundering, nepotism). Irrespective of its form, the phenomenon of corruption harms national economies because it hinders competition and innovation, discourages professionalism and entrepreneurial endeavors, and affects the structure of government spending and the country's image in the eye of potential investors (Mauro, 1997). As a consequence, investors might decide to concentrate their capital in other economies where fair competition and professionalism prevail.

Given the negative externalities corruption has on the business environment (Giannetti et al., 2017), researchers have focused on identifying the major determinants for control of corruption. Hence, Altunbaş and Thornton (2012) and Sharma and Paramati (2021) found that financial development (proxied by domestic credit to private sector by banks) tends to mitigate corruption. Regarding the relationship between control of corruption and CO_2 emissions, researchers report more on the impact of corruption on emission levels (Ifada, Chafsya, & Ihbal, 2024; Liu et al., 2021; Sundström et al., 2024). Nevertheless, a change of direction in this relationship (as we propose) could bring relevant insights on how to control corruption around the world. Moreover, studies also account for the negative impact of inflation on authorities' capacities to control corruption acts (Braun & Di Tella, 2004).

Determinants for rule of law

Rule of law is defined as a governance framework under which all citizens, businesses, and public institutions should abide by the same legal precepts and protects all human rights. This indicator weighs a great deal when investors choose between two potential markets. As expected, economies where authorities guarantee the right to private property, contract enforcement, and development gather more capital than societies that lack proper rule of law. The importance of the rule of law as a

societal institution has also been emphasized in the motivation of the newly awarded 2024 Nobel Prize in Economic Sciences, which states that countries "with poor rule of law and institutions that exploit the population do not generate growth or change for the better" (Nobel Prize Press Release, 2024). Consequently, we derive from this statement the fact that sustainable economic development cannot exist outside a strong rule of law.

Empirical studies on the factors influencing rule of law show (among others) the negative impact of inflation (Koyoma & Johnson, 2015; Paniagua, 2023), a strong connection between rule of law and environmental sustainability (Atta et al. 2024; Hilson, 2021; Sands, 2016), or credit institutions (Oto-Peralías & Romero-Ávila, 2017).

3. Research methodology

We investigate the impact of factors such as domestic credit to private sector by banks, CO_2 emissions from manufacturing industries and construction, annual inflation rate on annual GDP growth rate, control of corruption, and rule of law for the Brazilian market during the period 1996–2022 (see Table 1).

Table 1. Variable description and symbols.

Variable	Symbol	Definition
DEPENDENT VARIABLES		
Annual GDP growth rate (%)	GDPR	The variable is computed as the annual percentage growth rate of GDP at market prices, based on constant local currency.
Control of corruption	CC	The indicator measures perceptions regarding the degree to which public power is used for private gain, in addition to the degree to which elites and private interest control public authorities.
Rule of law	RL	The indicator measures perceptions regarding the degree to which agents are confident and follow society rules, namely the following aspects: the quality of contract enforcement, property rights, police, courts, the likelihood of crime and violence.
INDEPENDENT VARIABLES		
Domestic credit to private sector by banks (% of GDP)	DCB	The indicator captures the financial resources granted to private businesses by other depository corporations (except central banks), namely under the form of loans, purchases of nonequity securities, trade credits and other accounts receivable, that establish a claim for repayment.
CO_2 emissions from manufacturing industries and construction (% of total fuel combustion)	CO_2	The indicator comprises emissions from the combustion of fuels in industrial activities.
Annual inflation rate (consumer price index) (%)	INF	The indicator shows the annual percentage cost change for the average consumer who purchases a specific basket of goods and services.

Source: https://databank.worldbank.org/source/world-development-indicators# (accessed February 12, 2024).

We retrieved data from the World Development Indicators database commissioned by the World Bank. We focused on Brazil because it has one of the most important emerging economies, is a founding member of the BRICS group, and was listed as the ninth largest economy in the world in 2023 with a GDP of $2.3 trillion, following countries such as the US ($26.95 trillion), China ($17.7 trillion), Japan ($4.23 trillion), and India ($3.73 trillion). Brazil is also an economy with strong

advancements in industries such as agriculture, automotive, metallurgy, mining, petrochemicals, and steel, which yield the country's considerable annual GDP.

We chose the 27-year time frame because it is extended enough to capture important global events that shaped economies around the world and Brazil (Edwards, 1995, 2007), including the following: The 1997 Asian financial crisis; the 1998–1999 currency crisis; the 2008 global financial crisis; and the COVID-19 pandemic crisis and aftermath.

Empirical data were analyzed by means of time series data modeling and results were estimated via three methods: Least squares; fully modified least squares (FMOLS); and dynamic least squares (DOLS). The statistical software EViews version 10 was employed for the econometric analyses.

4. Results

We estimated three econometric models for each of the outcome variables chosen as a proxy for sustainable economic development: Annual GDP growth rate (GDPR); control of corruption (CC); and rule of law (RL). Before estimating the econometric models, we ran analyses of central tendency and correlation to check potential multicollinearity issues.

4.1. Analysis of central tendency and variation

We first determined descriptive statistics (i.e., mean, median, standard deviation, skewness, kurtosis, minimum and maximum values) to describe empirical data. Table 2 provides details on these statistics.

Table 2. Descriptive statistics.

Central tendency and variation statistics and tests	GDPR	CC	RL	DCB	CO_2	INF
Mean	2.1998	–0.1832	–0.2299	48.6760	25.8255	6.6172
Median	2.2089	–0.0908	–0.2383	47.4943	26.2370	6.3290
Maximum	7.5282	0.1684	0.0564	71.7765	27.8027	15.7577
Minimum	–3.5458	–0.5661	–0.4755	27.6857	20.6021	3.1951
Std. dev.	2.7668	0.2387	0.1388	15.7219	1.8654	3.0977
Skewness	–0.4156	–0.3416	0.3862	–0.0247	–1.6582	1.4887
Kurtosis	2.9433	1.5727	2.6239	1.3986	5.0876	5.2328
Jarque-Bera test	0.7808	2.5039	0.7379	2.8879	12.1578	15.5822
Probability	0.6768	0.2859	0.6914	0.2359	0.0023	0.0004
Observations	27	24	24	27	19	27

Source: Own computations.

According to the values of standard deviations from Table 2, the variables DCB, INF, and GDPR registered the largest volatility, while RL registered the smallest volatility. In terms of skewness, RL and INF were skewed to the right, while the rest were skewed to the left. Since kurtosis values for the variables CO_2 and INF were above the standard threshold of 3, we concluded that their distributions were leptokurtic. Furthermore, GDPR, CC, RL, and DCB had platykurtic distributions because kurtosis values corresponding to them were below the threshold of 3.

We also ran the Jarque-Bera test to check for the distribution of variables (Table 2). Our results indicated that CO_2 emissions and annual inflation rate were non-normally distributed at the 1% level. The rest of the dependent and independent variables were normally distributed.

4.2. Analysis of correlation

As a second step of our analysis approach, we determined pair-wise correlations to control for potential multicollinearity problems between predictors that could bias econometric estimations (see Table 3). According to the literature, multicollinearity could arise if correlation coefficients exceed the standard 0.9 threshold.

Table 3. Correlation matrix.

Indicators	GDPR	CC	RL	DCB	CO_2	INF
GDPR	1					
CC	0.246	1				
RL	–0.123	0.106	1			
DCB	–0.076	–0.339	0.767	1		
CO_2	0.389	0.708	–0.475	–0.769***	1	
INF	–0.230	0.234	–0.145	–0.236**	0.208*	1

Source: Own computations.

As seen from Table 3, the pairwise correlation coefficients corresponding to our predictors did not exceed the value of 0.9; therefore, we did not identify potential multicollinearity biases. In this context, the highest correlation coefficient was registered between the independent variables DCB and CO_2, while the lowest was reported for the pair of predictors CO_2–INF. Moreover, the results of the correlation analysis were supported by the variance inflation factors, which registered values below the standard threshold.

4.3. Econometric models

We advanced and tested the following research hypotheses:

H1: There is a significant connection between GDPR and DCB, CO_2, INF.
H2: There is a significant connection between CC and DCB, CO_2, INF.
H3: There is a significant connection between RL and DCB, CO_2, INF.

*T*he equation describing the general econometric model was:

$$\boldsymbol{Y_{it} = a_0 + a_1 X_{1t} + a_2 X_{2t} + a_3 X_{3t} + \delta + \theta_t + \varepsilon_t}$$

with,

- a_0 indicates the model intercept;
- a_i indicates the coefficient parameter, taking values from 1 to 3;
- *X* indicates the independent variables;
- *t* indicates the time frame 1996–2022;
- δ indicates the fixed effects, controlling for time-invariant country-specific factors;
- θ_t indicates the fixed effects controlling for common shocks (e.g., pandemic crisis);

- ε_t indicates the error term.

Table 4 displays the results of the econometric estimations for Brazil's economy.

Table 4. Econometric models corresponding to the dependent variable *annual GDP growth rate (GDPR).*

Variables	Variance inflation factor (VIF)	$Model\ GDPR = a_0 + a_1 DCB + a_2 CO2 + a_3 INF + \delta + \theta_t + \varepsilon_t$		
	-	Least Squares	Fully Modified Least Squares (FMOLS)	Dynamic Least Squares (DOLS)
C	-	–26.3257** (–2.3179)	–26.3257*** (–2.7832)	–22.9367*** (–2.6306)
DCB	2.3851	0.1075** (2.0528)	0.1075** (2.4649)	0.0839** (2.0850)
CO_2	2.3890	0.9996*** (2.6819)	0.9996*** (3.2204)	0.9031*** (3.1711)
INF	1.0428	–0.1408 (2.0367)	–0.1408 (–1.1957)	–0.1606 (–1.0969)
R^2	-	0.3439	0.3439	0.3210
Adjusted R^2	-	0.2127	0.2127	0.1755
F-statistic	-	2.6207	-	-
Prob(*F*-statistic)	-	0.0889	-	-
Observations	-	19	19	19

Source: Own computations.

Note: Robust *t*-statistics are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels. Prob.>*F* is the probability of not including fixed effects. Multicollinearity was investigated by means of the variance inflation factor (VIF). In case VIF values are below the standard threshold of 10, no obvious multicollinearity issues are identified.

Based on Table 4, we examined the evolution of the annual GDP growth rate via time series least squares (first model). As expected for the case of an emerging market that is also one of the chief industrial states, empirical results indicated a direct link between CO_2 and GDPR. In this sense, if CO_2 increased by one unit, GDPR would significantly rise by 0.999%. The strong connection between emissions and annual GDP growth rate is straightforward considering that more than half of the Brazilian GDP has been driven by the industry (including manufacturing and construction).

Our results also showed that domestic credit granted to the private sector by banks had a significant influence on GDPR. Hence, if DCB improved by 1%, the annual GDP growth rate would increase by 0.108 units. The positive impact of domestic credit on economic growth is in line with the country's newly enacted policy (i.e., New Industry Brazil), which entails the use of special credit lines addressed to private investors. For that matter, although the influence of credit is less intensive than the one of emissions, financial resources provided by the banking system to corporations and individuals are the lifeline of the economy. Corporations may use credits to refinance debt, expand production facilities, purchase assets, or invest in the capital market. Furthermore, individuals may use credit to start a business, acquire goods, and improve living conditions. Annual inflation rate had no significant impact on economic growth (Amato, 2023).

Overall, the adjusted coefficient of determination indicated that the combined effect of the independent variables explained 21.27% of the variance in the phenomenon GDPR. Therefore, the estimations of the first econometric model supported the first research hypothesis.

The robustness of the results yielded by the first model were confirmed by the second and third model (i.e., FMOLS, DOLS). In this sense, the same predictors played a significant role in the evolution of the annual GDP growth rate.

Table 5 displays the estimations of the predictors' impact on control of corruption.

Table 5. Econometric models corresponding to the dependent variable *control of corruption.*

Indicators	VIF	$Model\ CC = a_0 + a_1 DCB + a_2 CO2 + a_3 INF + \delta + \theta_t + \varepsilon_t$		
	-	Least Squares	Fully Modified Least Squares (FMOLS)	Dynamic Least Squares (DOLS)
C	-	–1.9669*** (–3.7650)	–2.1318*** (–4.5782)	–1.9669*** (–3.5425)
DCB	2.4893	0.0047* (1.8899)	0.0054** (2.4341)	0.0047* (1.7782)
CO_2	2.4567	0.0659*** (3.9114)	0.0710*** (4.7557)	0.0659*** (3.6801)
INF	1.0609	0.0046 (0.7249)	0.0069 (0.8959)	0.0046 (0.6821)
R^2	-	0.6220	0.6293	0.6220
Adjusted R^2	-	0.5275	0.5283	0.5275
F-statistic	-	6.5830	-	-
Prob(*F*-statistic)	-	0.0070	-	-
Observations	-	19	19	19

Source: Own computations.

Note: Robust *t*-statistics are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5% and 1% levels. Prob.>*F* is the probability of not including fixed effects. Multicollinearity was investigated by means of the variance inflation factor (VIF). In case VIF values are below the standard threshold of 10, no obvious multicollinearity issues are identified.

According to Table 5, in the first model, the set of independent variables explained 52.75% of the variance in the control of corruption phenomenon. More specifically, the predictors DCB and CO_2 played a considerable role in shaping the control of corruption. Similar to the previous econometric estimations, CO_2 emissions counted more for the changes in control of corruption. Therefore, when CO_2 increased by one unit, the score for control of corruption would rise by 0.066 units. Moreover, if DCB increased by 1%, the control for corruption phenomenon would rise by 0.005. Again, the impact of the annual inflation rate was not significant.

The other two estimation models (FMOLS, DOLS) yielded similar results and supported the second research hypothesis.

Table 6 comprises the econometric estimations corresponding to the dependent variable capturing rule of law in Brazil.

Table 6. Econometric models corresponding to the dependent variable *rule of law.*

Indicators	VIF	$Model\ RL = a_0 + a_1 DCB + a_2 CO2 + a_3 INF + \delta + \theta_t + \varepsilon_t$		
	-	Least Squares	Fully Modified Least Squares (FMOLS)	Dynamic Least Squares (DOLS)
C		–1.3506** (–1.8931)	-	-
DCB	2.4894	0.0121*** (0.0121)	0.0075*** (3.0544)	0.0066** (2.4399)
CO_2	2.4567	–0.0232*** (–1.0083)	–0.0188*** (–3.0612)	–0.0196*** (–3.1753)
INF	1.0609	0.0015 (0.1686)	–0.0074 (–0.4664)	0.0002 (0.0182)
R^2		0.6222	0.4881	0.5094
Adjusted R^2		0.5278	0.4028	0.4339
F-statistic		6.5883	-	-
Prob(*F*-statistic)		0.0070	-	-
Observations		19	19	19

Source: Own computations.

Note: Robust *t*-statistics are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5% and 1% levels. Prob.>*F* is the probability of not including fixed effects. Multicollinearity was investigated by means of the variance inflation factor (VIF). In case VIF values are below the standard threshold of 10, no obvious multicollinearity issues are identified.

Regarding the dependent variable RL, the model estimated with least squares indicated that the predictors DCB and CO_2 had a relevant role in shaping RL. In this context, if domestic credit by banks increased by one unit, the outcome rule of law would follow the same trend with a statistically significant increase of 0.012%. Furthermore, if CO_2 emissions decreased by one unit, the phenomenon capturing the rule of law would increase by 0.023 units. Overall, the econometric model explained 52.78% of the variance in the dependent variable.

The other two econometric models estimated via fully modified least squares and dynamic least squares reported similar results with respect to the impact of domestic credit to the private sector by banks.

Overall, our empirical results indicated that the third research hypothesis was also supported.

5. Conclusions

Nowadays, there is a high demand for financial resources across all economies, especially in numerous developing nations that register some of the fastest growing populations (Brida et al., 2024; Kapuria-Foreman, 1995; Miladinov, 2023), including Brazil (Bello, 2024). Still, these nations should aim to attain economic development within a sustainable framework (Afshan et al., 2024; Coleman, 2024) and adequately manage their host of natural resources (Mideksa, 2013; Nassif, Feijo, & Araujo, 2013).

We investigated the long-term connection between sustainable economic development (proxied by annual GDP growth rate, control of corruption, rule of law) and macroeconomic indicators related to domestic credit granted to the private sector, CO_2 emissions, and annual inflation rate. We focused on the Brazilian market because of its top ranking among developing nations, emerging markets, and the world's leading economies. In essence, Brazil is the largest economy in Latin America and the Caribbean, yielding an annual GDP of almost three trillion dollars.

Analyses were conducted for the time span 1995–2022 with time series data modeling via estimation methods such as least squares, fully modified least squares, and dynamic least squares. In a nutshell, we built three econometric models for each of the proxies for sustainable economic development and estimated the impact of the chosen macroeconomic indicators. Prior to running the models, we ruled out multicollinearity by means of correlation analysis and variance inflation factors. Therefore, we concluded that model estimations were bias free from multicollinearity issues.

Econometric results supported our research hypotheses and indicated that the predictors domestic credit granted by the banking system and CO_2 emissions from manufacturing industries and construction had a significant impact on the outcomes in all models. First, we found a relevant influence of CO_2 emissions on the annual GDP growth rate, which is straightforward since the Brazilian economy relies heavily on industry – besides agriculture – and industrial activities account for 24% of the country's GDP (New Zealand Foreign Affairs & Trade, 2023). In this context, Brazil is a leading manufacturer of automotives, oil and gas, iron and steel, machinery and equipment, and textiles. In relation to GDP growth rate, we also observed a significant influence of domestic credit by banks, with economic growth registering an ascending trend as more banks agreed to finance business endeavors. This crediting aspect is fundamental, especially in developing and emerging markets where numerous aspiring entrepreneurs have limited access to financial resources despite their great potential (Domeher & Abdulai, 2012).

Second, econometric estimations showed that control of corruption scores were positively influenced by CO_2 emissions and domestic credit by banks. Hence, a growing percentage of emissions – stemming from intensified industrial activities – was associated with better corruption control. One possible explanation for this result would be that growing economic activities (especially in leading industrial sectors) could impel public authorities to fight corruption and improve country scores, thus encouraging other potential investors to choose the Brazilian market. Our choice to include control of corruption among proxies for sustainable economic development resides in that corruption was and still is a rampant issue of the Brazilian economy (Goncalves & Srinivasan, 2019), which severely impedes its economic development (France, 2019). In addition, we found that domestic credit was statistically relevant for advancements regarding control of corruption. We infer that when the banking system supports private initiatives and eases access to credit lines, public authorities are more incentivized to monitor the economic environment and clamp down on corruption.

Third, the rule of law phenomenon was also impacted by CO_2 emissions and domestic credit by banks. Similar to the previous reasoning, more credit lines open for private investors would motivate authorities to enact efficient laws that secure private property, protect human rights, and create a safe environment for businesses to thrive. Furthermore, a limitation on emissions would translate into a well-functioning legal system that supports economic development and private investments.

Our results showed that predictors contributed to higher GDP rates, tighter control on corruption, and a stronger rule of law in Brazil across almost three decades. Nevertheless, the study has limitations. The period of analysis spanned 27 years to include relevant economic downturns from history.

Researchers could focus on broader periods of time and encompass other events that shaped Brazil's economic development. In addition, the set of predictors was limited to aspects regarding domestic credit, carbon dioxide emissions, and inflation. Upcoming research could investigate changes in sustainable economic development by means of other relevant macroeconomic indicators.

Overall, the Brazilian economy has substantial natural and human resources to continuously grow (World Economic Forum, 2018) and achieve a green economy in the coming years (Gouvea & Montoya, 2014). Although Brazil has registered certain progress concerning the low carbon economy, such attempts are quite scarce compared to the potential of the country. Spilimbergo and Srinivasan (2019) provided an in-depth analysis of the Brazilian economy after the 1980s and recommend six policies that could enhance a sustained growth: 1) Decrease capital cost via fiscal reforms; 2) mitigate tax burden, bureaucracy, and frequent changes in the tax code; 3) streamline legislation and lower legal risks; 4) intensify privatization and grant loans/subsidies to "socially attractive projects"; 5) integrate national economy into the global one; and 6) heighten firm competition to clear the market from unproductive companies. As can be inferred from the fourth suggested policy, domestic credit should be directed towards businesses that have growth potential (especially on international markets), provide higher-productivity jobs, and comply with the tax code.

Author contributions

All authors have contributed equally to the development and writing of this article.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

The authors declare no conflicts of interest in this paper.

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