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# The effect of business regulations, property rights, and legal system on CO<sub>2</sub> emissions: empirical evidence from the BRICS-T countries

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Global CO<sub>2</sub> emissions have continued to rise, although the rate of increase has begun to slow down due to environmental measures implemented at both international and national levels. Therefore, the results of empirical studies on the drivers of CO<sub>2</sub> emissions have been crucial for design of the appropriate environmental policies. This research article explores the interaction amongst business regulations, property rights, legal system, income, urbanization, and CO<sub>2</sub> emissions in the BRICS-T countries for the 2000–2021 duration by means of the novel causality and cointegration tests sensitive to heterogeneity and cross-section dependence. The results of the causality test reveal a mutual interplay amongst business regulations, property rights, urbanization and CO<sub>2</sub> emissions and a unidirectional causality from income to CO<sub>2</sub> emissions. Furthermore, the results of the long-run analysis also indicate that improvements in legal quality and property rights decrease CO<sub>2</sub> emissions while business regulations, real GDP per capita, and urbanization increase CO<sub>2</sub> emissions. Therefore, improvements in property rights and the legal system are vital for decreasing CO<sub>2</sub> emissions. However, negative environmental effects of market-oriented business regulations, income, and urbanization should be balanced by stringent environmental policies.

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## Introduction

The remarkable global increases in CO<sub>2</sub> emissions have been among the priority items of the global agenda because CO<sub>2</sub> emissions are accepted as one of the main factors behind climate change, global warming, and many health problems including drowsiness, and increased cardiac output (Jacobson et al. 2019). Therefore, the United Nations Environment Program (UNEP) was founded in 1972 and has led the environmental programs to deal with the environmental programs together with the member states (UNEP 2024a). Furthermore, nearly all the sustainable development goals adopted in 2025 by the UN members have direct and indirect connections with the environment (UNEP 2024b).

However, global CO<sub>2</sub> emissions have reached 39.024 billion metric tons in 2023 from 22.680 billion metric tons in 1990 and China, the United States, India, the EU-27, Russia, and Japan were the leading drivers of global CO<sub>2</sub> emissions as seen in Fig. 1 as of 2023 (Crippa et al. 2024). Nearly 90% of global CO<sub>2</sub> emissions come from the fossil fuels used for electricity, transport, and heat and the share of coal, oil, and natural gas are 40, 32, and 21%, respectively (CSIRO (Commonwealth Scientific and Industrial Research Organization (CSIRO 2024).

The factors underlying CO<sub>2</sub> emissions have been commonly explored in empirical studies and various institutional, energy-related, socio-economic factors have been suggested as the drivers of CO<sub>2</sub> emissions as seen in Table 1. A large part of these empirical studies has focused on the effect of economic indicators, population, urbanization, foreign direct investments, trade indicators, and energy indicators on environmental indicators, but effect of legal and institutional indicators on environment has been relatively little studied as seen in Table 1. Considering the gap in the associated empirical literature, the objective of this research is to examine the short and long-term effect of business regulations, legal system, property rights, income, urbanization, and CO<sub>2</sub> emissions in the BRICS-T (Brazil, Russia, India, China, South Africa, and Türkiye) countries which have been the top global CO<sub>2</sub> emitters.

This research targets to make two contributions to the associated empirical literature. In the empirical literature, only Gani and Sharma (2009), Rieger (2019), and Sezgin et al. (2024), and Güney (2024) have studied the nexus between business environment indicators and CO<sub>2</sub> emissions and revealed mixed results. On the other hand, the nexus between property rights and CO<sub>2</sub> emissions has been investigated only by Kerekes (2011), Donis et al. (2023), and Viglioni et al. (2024) and these researchers have uncovered that improvements in property rights contribute to the environmental protection. Therefore, this research will be one of the preliminary empirical studies which investigates the role of business regulations and property rights in the policies of environmental protection. Secondly, use of the AMG (augmented mean group) estimator, responsive to cross-sectional dependence

(CD) and heterogeneity, permits us to perform an analysis at country and panel levels unlike the regression approach widely used in the associated empirical literature. The remainder of the paper is organized as follows: Section “Literature review” summarizes the previous literature, while Section “Data and methodology” defines the dataset and explains the econometric methodology of the research. Section “Results and discussion” performs the empirical applications tests and discusses their outcomes. Last, Section “Conclusion” introduces conclusions and recommendations based on empirical results.

## Literature review

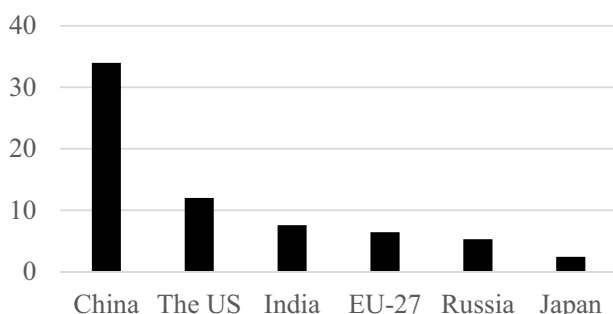
The remarkable environmental impairment has led the researchers to explore the factors underlying environmental degradation and many socio-economic, energy related, and institutional factors have been identified as the drivers of environmental impairment. However, the nexus among business regulations, property rights, and CO<sub>2</sub> emissions have not been sufficiently researched until today as seen in Table 1. Therefore, we examine the short and long-term interplay among business regulations, property rights, income, urbanization, and CO<sub>2</sub> emissions in BRICS-T countries.

Business regulations refer to administrative requirements, bureaucratic costs, business establishment procedures, licensing restrictions, tax compliance costs, and extra payments, bribes, and favoritism for the firms (Fraser Institute 2024a). Therefore, business regulations determine the environment which businesses operate in and in turn are important for economic activity. Therefore, market-oriented business regulations can impact the environment through fostering economic activity. However, country-specific characteristics such as economic development level and environmental policy stringency would be determinative for the nexus between business regulations and CO<sub>2</sub> emissions. In this context, a few studies have empirically analyzed the effect of business environment indicators on CO<sub>2</sub> emissions and uncovered the results supporting these theoretical considerations. On the one hand, Gani and Sharma (2009), Rieger (2019), and Sezgin et al. (2024) found a positive relationship between positive business environment and CO<sub>2</sub> emissions, but Güney (2024) unveiled a negative effect of business climate on CO<sub>2</sub> emissions.

Gani and Sharma (2009) explored the nexus between procedures of starting a business and CO<sub>2</sub> emissions for the year of 2003 in both developing and developed countries by regression and uncovered a negative relationship between procedures of starting a business and CO<sub>2</sub> emissions. On the other hand, Rieger (2019) explored the nexus between business environment proxied by doing business index and CO<sub>2</sub> emissions in the developing economies for the 2005–2014 term through regression and uncovered a positive influence of doing business index on CO<sub>2</sub> emissions in the developing countries.

Sezgin et al. (2024) explored the relationship between business environment represented by private sector index of UNCTAD-STAT and CO<sub>2</sub> emissions in the BRICS economies between 2000 and 2020 by means of cointegration and causality tests and revealed a bilateral causal association between CO<sub>2</sub> emissions and business climate and business environment positively affected CO<sub>2</sub> emissions in Russian Federation, South Africa, and China. Adversely, Güney (2024) investigated the influence of business environment on CO<sub>2</sub> emissions in OECD members for the 2007–2020 period by regression and unveiled a negative influence of business environment on CO<sub>2</sub> emissions.

Last, Aydıntuğ Myrvang et al. (2023) also analyzed the relationship between business regulations and sustainable development in the EU transition countries by causality and



**Fig. 1** The leading CO<sub>2</sub> emitter in the world (2023, % of global CO<sub>2</sub> emissions).

**Table 1 Impact of institutional, socio-economic, and energy-related factors on CO<sub>2</sub> emissions.**

| Factors                 | Studies                                                                                  |                                                                                                                                                                       |                                                                                                                                     |
|-------------------------|------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
|                         | Positive                                                                                 | Negative                                                                                                                                                              | Insignificant                                                                                                                       |
| Institutional factors   | Government effectiveness                                                                 | Abid (2016)                                                                                                                                                           | Abid (2016)                                                                                                                         |
|                         | Regulatory quality                                                                       | Abid (2016)                                                                                                                                                           | Amin et al. (2022)                                                                                                                  |
|                         | Rule of law                                                                              | Abid (2016)                                                                                                                                                           | Amin et al. (2022)                                                                                                                  |
|                         | Corruption                                                                               | Abid (2016)                                                                                                                                                           | Abid (2016)                                                                                                                         |
| Socio-economic factors  | Democratization, voice and accountability                                                | Gani and Sharma (2009), Rieger (2019), and Sezgin et al. (2024)                                                                                                       | Abid (2016)                                                                                                                         |
|                         | Business environment                                                                     |                                                                                                                                                                       | Güney (2024)                                                                                                                        |
|                         | Property rights                                                                          |                                                                                                                                                                       | Kerekes (2011), Donis et al. (2023), and Viglioni et al. (2024)                                                                     |
|                         | Political stability                                                                      |                                                                                                                                                                       | Abid (2016)                                                                                                                         |
| Energy- related factors | Political polarization                                                                   | Sharma (2011), Abid (2016), Aller et al. (2021), Zhao et al. (2022), Onofrei et al. (2022), Ali et al. (2023), Arshad and Parveen (2024), and Mukhtarov et al. (2024) | Aller et al. (2021)                                                                                                                 |
|                         | GDP, GDP per capita, economic growth                                                     |                                                                                                                                                                       |                                                                                                                                     |
|                         | Population                                                                               | Zhao et al. (2022) and Arshad and Parveen (2024)                                                                                                                      |                                                                                                                                     |
|                         | Inflation                                                                                | Mukhtarov et al. (2024)                                                                                                                                               | Grolleau and Weber (2024)                                                                                                           |
| Energy- related factors | Financial development                                                                    | Arshad and Parveen (2024)                                                                                                                                             | Amin et al. (2022)                                                                                                                  |
|                         | Financial inclusion                                                                      |                                                                                                                                                                       |                                                                                                                                     |
|                         | Education                                                                                | Khoshnevis Yazdi and Dariani (2019), Aller et al. (2021), Amin et al. (2022), Lugman et al. (2023), and Arshad and Parveen (2024)                                     | Sharma (2011)                                                                                                                       |
|                         | Urbanization                                                                             |                                                                                                                                                                       |                                                                                                                                     |
| Energy- related factors | Industrialization                                                                        | Aller et al. (2021)                                                                                                                                                   |                                                                                                                                     |
|                         | FDI                                                                                      | Amin et al. (2022), Arshad and Parveen (2024) and Justice et al. (2024)                                                                                               |                                                                                                                                     |
|                         | Trade, trade openness, export, import                                                    | Sharma (2011) and Abid (2016)                                                                                                                                         | Amin et al. (2022), Arshad and Parveen (2024), and Mukhtarov et al. (2024)                                                          |
|                         | Non-renewable energy consumption, primary energy consumption, electric power consumption | Sharma (2011), Aller et al. (2021), and Zhao et al. (2022)                                                                                                            | Justice et al. (2024)                                                                                                               |
| Energy- related factors | Energy intensity                                                                         |                                                                                                                                                                       |                                                                                                                                     |
|                         | Energy efficiency                                                                        | Zhao et al. (2022)                                                                                                                                                    |                                                                                                                                     |
|                         | Renewable energy use and development of renewable energy technologies                    |                                                                                                                                                                       | Mirza et al. (2022), Azizi et al. (2024)                                                                                            |
|                         |                                                                                          |                                                                                                                                                                       | Szetela et al. (2022), Amin et al. (2022), Jiang and Liu (2022), Justice et al. (2024), Azizi et al. (2024), and Soto et al. (2025) |

Mukhtarov et al. (2024)

cointegrations tests and disclosed a significant causal effect from business regulations to sustainable development and a positive long-term influence of market-oriented business regulations on overall sustainable development.

Based on the associated literature, the first research hypothesis of the article is formed as follows:

**H1:** Business regulations have a significant influence on CO<sub>2</sub> emissions.

Property rights enable entrepreneurs and firms to receive benefit from innovation in terms of new green production methods and green or energy-efficient technologies which can foster environmental quality (Kerekes 2011). Furthermore, property rights can contribute to environmental quality through internalizing the costs of environmental pollution (Demsetz 1967). Therefore, a negative impact of improvements in property rights on CO<sub>2</sub> emissions is theoretically expected. However, only Kerekes (2011), Donis et al. (2023), and Viglioni et al. (2024) studied the nexus between property rights and CO<sub>2</sub> emissions and revealed the findings supporting the theoretical expectations.

Kerekes (2011) investigated the effect of property rights on environmental quality by regression approach and uncovered that improvement in the property rights negatively affected the air quality, but positively impacted water and land quality. On the other hand, Donis et al. (2023) investigated the relationship among legal system, property rights, economic complexity, and eco-innovation in the OECD countries between 2007 and 2016 by means of regression and unveiled that intellectual property rights and effectiveness of the judicial system had a positive effect on green patent production. Last, Viglioni et al. (2024) investigated the effect intellectual property rights on the nexus between foreign direct investments and CO<sub>2</sub> emissions in G20 countries between 2001 and 2017 by means of regression and causality approaches. Their results pointed out that there is a decreasing effect of property rights on CO<sub>2</sub> emissions and a bilateral causal interaction between property rights and CO<sub>2</sub> emissions.

Based on the associated literature, the second research hypothesis of the article is formed as follows:

**H2:** Property rights have a significant influence on CO<sub>2</sub> emissions.

Rules of law can impact the environment through multiple channels. In this context, the theoretical model by Fredriksson and Mani (2002) based on Grossman and Helpman (1994) suggests two opposite effects on the nexus between rule of law and environmental protection. On the one hand, improvements in the rule of law can contribute to environmental protection through supporting the stringency of environmental policies and adoption of circularity by the firms (Losa 2025). On the other hand, it can negatively impact the environment through raising the corruption level. Furthermore, an effectively functioning legal system enables the persons and firms to comply more with environmental regulations and in turn increases environmental quality (Mahmood and Alanzi 2020). In conclusion, the net effect of rules of law on the environment depends on which factors are dominant. In the empirical literature, the nexus between indicators of legal system and CO<sub>2</sub> emissions have been empirically analyzed by relatively more researchers and these studies have uncovered different results incompatible with the related theoretical considerations. On the one hand, Fredriksson and Mani (2002), Mahmood and Alanzi (2020), Muhammad and Long (2021), Khan et al. (2023), and Stef et al. (2023) discovered a negative association between rule of law and CO<sub>2</sub> emissions. However, Mahmood et al. (2021) unveiled an insignificant long-term effect on CO<sub>2</sub> emissions. Abid (2016) and Mahmood et al. (2022) discovered a positive effect of rule of law on CO<sub>2</sub> emissions.

Fredriksson and Mani (2002) examined the relationship among rule law, corruption, and environmental policy stringency in 83

countries by means of regression and discovered a positive influence of rule of law on stringency of environmental policy, but a negative effect of corruption on stringency of environmental policy. On the other hand, Mahmood and Alanzi (2020) also examined the effect of rule of law on CO<sub>2</sub> emissions in Saudi Arabia between 1996 and 2014 and unveiled a negative relation between rule of law and CO<sub>2</sub> emissions.

Muhammad and Long (2021) also examined the effect of rule of law, corruption, and political stability on CO<sub>2</sub> emissions in belt and road initiative countries between 2000 and 2016 through cointegration and regression approaches and unveiled a negative effect of rule of law and other institutional factors on CO<sub>2</sub> emissions. Amin et al. (2022) explored the drivers of CO<sub>2</sub> emissions in China for the 1996–2020 term through dynamic autoregressive distributed lag simulations and unveiled a negative effect of rule of law on CO<sub>2</sub> emissions.

Khan et al. (2023) analyzed the effect of rule of law and natural resources on CO<sub>2</sub> emissions in the BRICS countries for the period of 1990–2021 through regression approach and disclosed a negative effect of rule of law on CO<sub>2</sub> emissions. Stef et al. (2023) analyzed the effect of institutional, energy, socio-educational, and macroeconomic factors on CO<sub>2</sub> emissions in 217 countries between 1996 and 2016 through artificial intelligence models and rule of law is found to be the most effective instrument in decreasing CO<sub>2</sub> emissions.

However, Mahmood et al. (2021) investigated the relationship among rule of law, corruption, and CO<sub>2</sub> emissions in Pakistan for the 1996–2019 via ARDL approach and found that rule of law negatively affected CO<sub>2</sub> emissions in the short term but had an insignificant effect on CO<sub>2</sub> emissions in the long term.

Abid (2016) explored the effect of institutional, financial, and economic variables on CO<sub>2</sub> emissions in the Sub-Saharan Africa economies through static and dynamic regression approaches and discovered a positive effect of rule of law on CO<sub>2</sub> emissions. Mahmood et al. (2022) examined the relation amongst CO<sub>2</sub> emissions, rule of law, and regulatory quality in 4 South Asian states for the period of 1996–2019 through cointegration test and discovered a positive association between rule of law and CO<sub>2</sub> emissions.

Based on our literature summary, the third research hypothesis of the article is formed as follows:

**H3:** Legal system has a significant influence on CO<sub>2</sub> emissions.

The nexus between income and environmental indicators in the context of EKC (Environmental Kuznets Curve) hypothesis which suggests a non-monotonic interaction between economic development level and environment (Grossman and Krueger 1995) has been extensively studied in the empirical literature. On the one hand, Awan and Azam (2022) revealed a N interaction between income and CO<sub>2</sub> emissions for G20 countries and Akbostancı et al. (2009) uncovered an inverted U interaction between income and CO<sub>2</sub> emissions in Türkiye. Furthermore, Sharma (2011), Abid (2016), Aller et al. (2021), Zhao et al. (2022), Onofrei et al. (2022), Ali et al. (2023), Arshad and Parveen (2024), and Mukhtarov et al. (2024) discovered a positive impact of economic growth indicators on CO<sub>2</sub> emissions. Wang et al. (2020), Topcu et al. (2016), and Balli et al. (2020), respectively, discovered a unidirectional causality from GDP per capita to CO<sub>2</sub> emissions in central and eastern provinces of China and Türkiye, while Wang (2018) uncovered a unidirectional causality from economic growth to CO<sub>2</sub> emissions in the developed countries.

Based on the associated literature, the fourth research hypothesis of the article is formed as follows:

**H4:** Income has a significant influence on CO<sub>2</sub> emissions.

Environmental effects of urbanization have also been extensively explored in the literature. Urban areas are usually wealthier and consume more energy when compared with the rural areas

**Table 2 Dataset description.**

| Variables | Description                                        | Standard deviation       |
|-----------|----------------------------------------------------|--------------------------|
| COE2      | CO <sub>2</sub> emissions (metric tons per capita) | Climate Watch (2024)     |
| BUS       | Business regulation index                          | Fraser Institute (2024b) |
| PROP      | Property rights index                              | Fraser Institute (2024b) |
| LEGAL     | Judicial independence index                        | Fraser Institute (2024b) |
| INCOME    | GDP per capita (constant 2015 US\$)                | World Bank (2025a)       |
| URB       | Urban population (% of total population)           | World Bank (2025b)       |

and in turn urbanization is expected to increase CO<sub>2</sub> emissions (Luqman et al. 2023). On the other hand, urbanization can contribute to the decreases at the CO<sub>2</sub> emissions at further economic development levels through low-emissions service emissions (Uchiyama 2016). Therefore, the net effect of urbanization on CO<sub>2</sub> emissions can be theoretically changed depending on economic development levels of the countries. Thus, Khoshnevis Yazdi and Dariani (2019), Aller et al. (2021), Amin et al. (2022), Luqman et al. (2023), and Arshad and Parveen (2024) revealed a positive effect of urbanization on CO<sub>2</sub> emissions while Sharma (2011) uncovered a negative effect of urbanization on CO<sub>2</sub> emissions. Furthermore, Topcu et al. (2016) discovered a unilateral causality from urbanization to CO<sub>2</sub> emissions in Türkiye. Similarly, Musa et al. (2021) uncovered a unidirectional causality from urbanization to CO<sub>2</sub> emissions in Nigeria. But Khoshnevis Yazdi and Dariani (2019) revealed a bidirectional causal nexus between urbanization and CO<sub>2</sub> emissions in Asian countries.

Based on the associated literature, the fifth research hypothesis of the article is formed as follows:

**H5:** Urbanization has a significant influence on CO<sub>2</sub> emissions.

### Data and methodology

This paper examines the nexus amongst CO<sub>2</sub> emissions, business regulations, legal system, property rights, real GDP per capita, and urbanization in the sample of BRICS-T for the 2000–2021 duration by way of the panel cointegration and causality tests incompatible with the dataset characteristics. The variables used in the empirical analysis are presented in Table 2 and all series for BRICS-T countries are complete for the 2000–2021 period. CO<sub>2</sub> emissions (COE2) are represented by CO<sub>2</sub> emissions (metric tons per capita) and are acquired from Climate Watch (2024). The independent variables of business regulations (BUS), legal system (LEGAL), and property rights (PROP) are respectively represented by the indexes of business regulation, judicial independence, and property rights calculated by Fraser Institute (2024b). The index of business regulations is calculated as a combination of administrative requirements, bureaucratic procedures, licensing restrictions, procedures of a business establishment, cost of tax compliance, and corruption and gets a value between 0 and 10 (Higher figures demonstrate that markets determine the prices and governments restrain from the activities which retard and increase the costs of establishing a firm and producing goods and services.) (Fraser Institute 2024a). The indexes of judicial independence, and property rights also get value between 0 and 10 and higher values indicate the improvements in legal system and property rights which are required for the efficient allocation of resources (Fraser Institute 2024b). Furthermore, income is represented by GDP per capita based on constant 2015 US\$ and urbanization is proxied by urban population as a percent of total population and these variables are acquired from World Bank (2025a and 2025b).

The study sample is formed from the BRICS-T countries because these countries are the drivers of the global economic growth in recent years, but China, India, and Russia also are

**Table 3 Summary statistics of the series.**

| Variables | Mean value | Standard deviation | Minimum | Maximum  |
|-----------|------------|--------------------|---------|----------|
| COE2      | 5.368      | 3.504              | 0.883   | 12.11    |
| BUS       | 4.404      | 0.784              | 2.521   | 6.849    |
| PROP      | 5.670      | 0.844              | 3.583   | 6.923    |
| LEGAL     | 5.443      | 1.276              | 3.544   | 7.432    |
| INCOME    | 6508.125   | 3131.33            | 756.704 | 13449.93 |
| URB       | 62.078     | 17.968             | 27.667  | 87.317   |

among the top global CO<sub>2</sub> emitters (Crippa et al. 2024). The analysis period is between 2000 and 2021 because annual data of business regulations, property rights, and legal system are available as of 2000 and ends in 2021. Stata 17.0 and Gauss 16.0 are utilized to perform the econometric analyses. The summary indicators of COE2, BUS, LEGAL, PROP, INCOME, and URB are demonstrated in Table 3. In this connection, the average of CO<sub>2</sub> emissions per capita was 5.368 metric tons, but considerably differs amongst the BRICS-T countries. In addition, the averages of business regulations, property rights, and judicial independence indices are 4.404, 5.670, and 5.443 out of 10, respectively, but these indices display a relatively less variation among the BRICS-T countries. Lastly, average values of real GDP per capita and urbanization are respectively USD 6508.125 and 62.078% of total population. However, both real GDP per capita and urbanization remarkably varies among the BRICS-T states.

The essential objective of our research paper is to analyze the nexus amongst CO<sub>2</sub> emissions, business regulations, legal system, property rights, income, and urbanization. Therefore, the model in Eq. (1) is established for the purpose of empirical analyses:

$$COE_{it} = \alpha_0 + \beta_1 BUS_{it} + \beta_2 LEGAL_{it} + \beta_3 PROP_{it} + \beta_4 INCOME_{it} + \beta_5 URB_{it} + u_{it} \quad (1)$$

The short and long-term nexus amongst CO<sub>2</sub> emissions, business regulations, property rights, legal system, income, and urbanization is explored by means of the Westerlund and Edgerton (2008) cointegration test with structural breaks and JKS (Juodis-Karavias-Sarafidis 2021) causality test seeing the presence of heterogeneity and CD amongst the series. The Westerlund and Edgerton (2008) cointegration test accounts for CD, heterogeneity, structural breaks, autocorrelation and heteroscedasticity. The cointegration test statistics are derived using the following equations:

$$y_{i,t} = \alpha_i + \eta_i t + \delta_i D_{i,t} + x'_{i,t} \beta_i + (D_{i,t} X_{i,t})' \gamma_i + z_{i,t} \quad (2)$$

$$x_{i,t} = x_{i,t-1} + w_{i,t} \quad (3)$$

In the Eqs. (2) and (3),  $D_{it}$  represents the dummy variable. The coefficients  $\alpha_i$  and  $\beta_i$  are the constant and slope values before the structural break, while  $\delta_i$  and  $\gamma_i$  represent the changes after the structural break. The error terms are proxied by  $z_{i,t}$  and  $w_{i,t}$ . The structural breaks, endogenously specified within the cointegration test, uncovered significant effects resulting from



the global financial crisis, the Eurozone sovereign debt crisis and the national crises. These findings also substantiate the robustness of the cointegration test.

The causal nexus amongst CO<sub>2</sub> emissions, business regulations, property rights, legal system, income, and urbanization is examined by means of the JKS (2021) causality test developed for heterogeneous and homogenous panel datasets and the test is rest on (4) numbered equation (Juodis et al. 2021):

$$y_{it} = \pi_{0i} + \sum_{k=1}^k \delta_{pi} y_{i,t-k} + \sum_{q=1}^Q \varphi_{qi} X_{i,t-k} + \varepsilon_{it} \quad (4)$$

where *i* and *t* symbolizes BRICS-T countries and years, respectively.

In Eq. (4),  $X_{i,t}$  is a scalar variable and  $\delta_{p,i}$  and  $\varphi_{q,i}$  demonstrate the heterogeneous autoregressive effects and Granger causal effects, respectively.  $y_{i,t-k}$  is indicator of an autoregressive distributed lag under the null hypothesis, with  $\varphi_{qi} = 0$  for *I* and *q* (Juodis et al. 2021). The HPJ (Half Panel Jackknife) estimator is utilized to overcome the possible bias issue resulting from the pooled estimators. Furthermore, the HPJ estimator's variance can be specified by means of bootstrapping in case of CD presence. This test produces more robust results in the existence of heterogeneities and CD in panel datasets.

## Results and discussion

In the empirical part of our research paper, the starting step includes performing the CD and heterogeneity tests. Hence, LM (Lagrange Multiplier) (Breusch and Pagan, 1980), LM CD (Pesaran, 2004), and LM<sub>adj.</sub> (Pesaran et al., 2008) tests are first performed, and their outcomes are displayed in Table 4. The H<sub>0</sub> hypothesis, which posits CD independence, is disapproved at a 1%, uncovering the CD presence among CO<sub>2</sub>E, BUS, LEGAL, PROP, INCOME, and URB.

The presence of homogeneity is secondly examined by means of delta tilde tests of Pesaran and Yamagata (2008) and their outcomes are demonstrated in Table 5. The H<sub>0</sub> hypothesis, which posits homogeneity, is rejected at 1%, and the presence of heterogeneity is uncovered. In conclusion, utilization of econometric techniques considering the CD and heterogeneity is essential for reliability of the results.

The presence of unit root at the series of CO<sub>2</sub>E, BUS, PROP, LEGAL, INCOME, and URB is analyzed through PANKPSS unit root test with structural breaks developed by Carrion-i-Silvestre (2005) and Carrion-i-Silvestre et al. (2005) considering the presence of economic crises during the 2000–2021 period. The results presented in Table 6 uncover that the level values of all series have unit root because test statistics are found to be greater than critical values. But the first-differenced values of these variables do not include unit root. Furthermore, the results also uncover that especially 2008 global financial crisis, the Eurozone sovereign debt crisis, and national crises led structural breaks at the series.

The cointegration nexus amongst CO<sub>2</sub>E, BUS, PROP, LEGAL, INCOME, and URB is investigated by way of Westerlund and Edgerton (2008) cointegration test with structural breaks and its outcomes are displayed in Table 7. The outcomes of the test uncover a stable long-term relationship amongst the series,

because H<sub>0</sub> hypothesis of the test, which posits an insignificant cointegration nexus amongst the series, is rejected as p-value is lower than 5%. Furthermore, the results of the Johansen Fisher cointegration test in Table 8 uncover that there exist five significant cointegration relationships among the series.

The AMG estimator by Eberhart and Bond (2009) is utilized to specify the long-term coefficients of panel and BRICS-T countries, and the coefficients are displayed in Table 9. The panel coefficients demonstrate that the legal system negatively impacts CO<sub>2</sub> emissions while income positively affects CO<sub>2</sub> emissions. Furthermore, the coefficients of the BRICS-T countries demonstrate a positive influence of market-oriented business regulations on CO<sub>2</sub> emissions in Brazil, China, India, and South Africa. On the other hand, improvements in property rights decrease the

**Table 5 Outcomes of slope homogeneity test.**

| Test                    | Test statistic | P-value |
|-------------------------|----------------|---------|
| $\tilde{\Delta}$        | 6.330          | 0.002   |
| $\tilde{\Delta}_{adj.}$ | 7.666          | 0.000   |

**Table 6 Outcomes of the PANKPSS unit root test.**

| Variables | KPSS test statistics | PANKPSS critical values |         |         |
|-----------|----------------------|-------------------------|---------|---------|
|           |                      | 1%                      | 5%      | 10%     |
| CO        | 22.807               | 17.137                  | 21.298  | 30.900  |
| BUS       | 31.526               | 11.514                  | 17.127  | 30.703  |
| PROP      | 82.741               | 25.315                  | 32.946  | 51.786  |
| ROL       | 332.218              | 214.174                 | 286.034 | 484.726 |
| INCOME    | 310.053              | 202.341                 | 306.449 | 607.247 |
| URB       | 210.305              | 104.206                 | 171.445 | 461.808 |

| Countries          | Structural breaks at the series |      |      |      |        |      |
|--------------------|---------------------------------|------|------|------|--------|------|
|                    | CO                              | BUS  | PROP | ROL  | INCOME | URB  |
| Brazil             | 2009                            | 2005 | 2014 | 2006 | 2003   | 2003 |
|                    | 2012                            | 2014 |      | 2008 | 2007   | 2007 |
|                    | 2015                            |      |      |      | 2014   | 2010 |
| China              | 2003                            | -    | 2014 | 2010 | 2003   | 2003 |
|                    | 2006                            |      |      |      | 2007   | 2007 |
|                    | 2010                            |      |      |      | 2014   | 2010 |
| India              | 2006                            | -    | 2014 | 2006 | 2003   | 2003 |
|                    | 2009                            |      |      |      | 2006   | 2006 |
|                    | 2013                            |      |      |      | 2014   | 2010 |
| Russian Federation | -                               | -    | 2010 | 2013 | 2003   | 2003 |
|                    |                                 |      |      |      | 2006   | 2006 |
|                    |                                 |      |      |      | 2014   | 2010 |
| South Africa       | 2015                            | -    | 2013 | 2014 | 2002   | 2002 |
|                    | 2018                            |      |      |      | 2006   | 2006 |
|                    |                                 |      |      |      | 2013   | 2010 |
| Türkiye            | 2005                            | 2010 |      | 2008 | 2002   | 2002 |
|                    | 2010                            | 2014 |      | 2016 | 2006   | 2006 |
|                    | 2015                            |      |      | 2017 | 2013   | 2010 |

**Table 7 Outcomes of Westerlund and Edgerton cointegration test.**

| Model                                                                                                     | $Z_{\varphi}(N)$ | P-value | $Z_{\tau}(N)$ | P-value |
|-----------------------------------------------------------------------------------------------------------|------------------|---------|---------------|---------|
| Düzeyde Kırılma (level shift)                                                                             | -1.515**         | 0.044   | -3.508***     | 0.000   |
| Structural break                                                                                          |                  |         |               |         |
| Brazil (2010), China (2010), India (2010), Russian Federation (2010), South Africa (2010), Türkiye (2010) |                  |         |               |         |

**Table 4 Outcomes of CD test.**

| Test   | Test statistic | P-value |
|--------|----------------|---------|
| LM     | 32.45          | 0.0002  |
| LM adj | 4.807          | 0.0200  |
| LM CD  | 5.023          | 0.0000  |

**Table 8 Outcomes of Johansen Fisher cointegration test.**

| Hypothesized no. of CE(s) | Fisher Stat. (from trace test) | P-value | Fisher Stat. (from max-eigen test) | P-value |
|---------------------------|--------------------------------|---------|------------------------------------|---------|
| None                      | 342.5                          | 0.0000  | 171.5                              | 0.0000  |
| At most 1                 | 238.6                          | 0.0000  | 128.5                              | 0.0000  |
| At most 2                 | 145.2                          | 0.0000  | 84.01                              | 0.0000  |
| At most 3                 | 77.30                          | 0.0000  | 38.62                              | 0.0001  |
| At most 4                 | 53.01                          | 0.0000  | 34.26                              | 0.0006  |
| At most 5                 | 45.65                          | 0.0000  | 45.65                              | 0.000   |

Optimal lag length is determined based on Schwarz information criterion.

**Table 9 Long-term coefficients of panel and BRICS-T countries.**

| Countries    | BUS                 | PROP                | LEGAL               | INCOME             | URB                |
|--------------|---------------------|---------------------|---------------------|--------------------|--------------------|
| Brazil       | 0.166 <sup>a</sup>  | −0.356 <sup>a</sup> | −0.316 <sup>a</sup> | 0.462              | 0.251              |
| China        | 0.242 <sup>a</sup>  | −0.173 <sup>a</sup> | −0.662 <sup>a</sup> | 5.387 <sup>b</sup> | 0.048 <sup>a</sup> |
| India        | 0.0403 <sup>c</sup> | −0.171 <sup>b</sup> | −0.015 <sup>a</sup> | 1.644 <sup>b</sup> | 0.053 <sup>a</sup> |
| Russia       | −0.018              | −0.294              | 0.127               | 2.169 <sup>b</sup> | 2.14               |
| South Africa | 0.245 <sup>c</sup>  | 0.019               | −0.309 <sup>a</sup> | 6.613 <sup>b</sup> | 0.024 <sup>a</sup> |
| Türkiye      | −0.059              | −0.204              | −0.074 <sup>a</sup> | 2.822 <sup>b</sup> | 0.031 <sup>a</sup> |
| Panel        | 0.021               | −0.197 <sup>b</sup> | −0.098              | 3.183 <sup>b</sup> | 0.391              |

<sup>a,b</sup>, and <sup>c</sup> demonstrate they are significant at a 1, 5, and 10% level, respectively.

CO<sub>2</sub> emissions in Brazil, China, and India and improvements in legal system decrease the CO<sub>2</sub> emissions in Brazil, China, India, South Africa, and Türkiye. In addition, income has a positive impact on CO<sub>2</sub> emissions in China, India, Russia, South Africa, and Türkiye and urbanization positively impacts CO<sub>2</sub> emissions in China, India, South Africa, and Türkiye.

Business regulations set the environment which the firms operate in and the procedures for the start of new firms. Therefore, business regulations can impact CO<sub>2</sub> emissions through economic activity level in a country, but the effect of business regulations on CO<sub>2</sub> emissions can vary depending on the stringency of environmental policies in force and economic development levels of the countries. Thus, Gani and Sharma (2009), Rieger (2019), and Sezgin et al. (2024) also uncovered a positive effect of positive business environment on CO<sub>2</sub> emissions while Güney (2024) unveiled a negative effect of business climate on CO<sub>2</sub> emissions. However, our results indicate that business regulations positively affect CO<sub>2</sub> emissions in Brazil, China, India, and South Africa in the long-term incompatible with the findings of Gani and Sharma (2009), Rieger (2019), and Sezgin et al. (2024). The positive effect of business regulations on CO<sub>2</sub> emissions can be resulted from the relatively looser environmental policies because the environmental performance indices of Brazil, South Africa, China, and India in 2024 are respectively 53.00, 42.7, 35.40, and 27.60 (Yale Center for Environmental Law & Policy 2024). Furthermore, the average value of environmental policy stringency index of Brazil, China, India, and South Africa out of 6 over the 2000–2020 period is 0.538, 1.602, 1.782, and 0.717 (OECD 2025). In conclusion, our findings support the validity of the first hypothesis of the study based on the associated literature.

On the other hand, property rights can contribute to environmental protection through multiple channels at theoretical terms. The protection of property rights encourages entrepreneurs and firms to develop green production methods and green or energy-efficient technologies. Furthermore, property rights can

contribute to environmental quality through internalization of costs related to environmental pollution. The limited empirical literature including Kerekes (2011), Donis et al. (2023), and Viglioni et al. (2024) also uncovered the findings supporting these theoretical expectations. Similarly, our results also indicate that improvements in property rights decrease the CO<sub>2</sub> emissions at panel level and in Brazil, China, and India incompatible with the associated literature. In conclusion, our results support the validity of the second hypothesis of the study based on the associated literature.

The theoretical views on the nexus between the legal system and environment indicate that the legal system can impact CO<sub>2</sub> emissions via different channels. On the one hand, the improvements in rule of law can contribute to the environmental protection through supporting the stringency of environmental policies and adoption of circularity by the firms (Fredriksson and Mani 2002; Losa 2025). On the other hand, it can negatively impact the environment through raising the corruption level (Fredriksson and Mani 2002). In addition, an effectively functioning legal system can decrease CO<sub>2</sub> emissions by increasing compliance with environmental regulations. In line with these theoretical considerations, the empirical studies have also reached different results. In this context, Fredriksson and Mani (2002), Mahmood and Alanzi (2020), Muhammad and Long (2021), Khan et al. (2023), and Stef et al. (2023) discovered a negative effect of rule of law on CO<sub>2</sub> emissions while Abid (2016) and Mahmood et al. (2022) discovered a positive effect of rule of law on CO<sub>2</sub> emissions. Our findings indicate that improvements in legal system negatively impact CO<sub>2</sub> emissions in Brazil, China, India, South Africa, and Türkiye incompatible with the results of Fredriksson and Mani (2002), Mahmood and Alanzi (2020), Muhammad and Long (2021), Khan et al. (2023), and Stef et al. (2023). In conclusion, our findings verify that negative effects of legal quality on CO<sub>2</sub> emissions outweigh the positive effect of legal quality on CO<sub>2</sub> emissions and support the validity of the third hypothesis of the study based on the associated literature.

The relationship between income and CO<sub>2</sub> emissions is one of the most explored topics in the literature. However, the effect of income on CO<sub>2</sub> emissions can be changed depending on economic development level and environmental policies in force and environmental awareness in a country. The related empirical literature has also reached mixed results similarly to these theoretical considerations. In this regard, Akbostancı et al. (2009) and Awan and Azam (2022) respectively revealed a N interaction and an inverted U interaction between income and CO<sub>2</sub>. In addition, Sharma (2011), Abid (2016), Aller et al. (2021), Zhao et al. (2022), Onofrei et al. (2022), Ali et al. (2023), Arshad and Parveen (2024), and Mukhtarov et al. (2024) revealed a positive relationship between economic indicators and CO<sub>2</sub> emissions. In a similar vein, our findings also unveil a positive relationship between real GDP per capita and CO<sub>2</sub> emissions at panel and in China, India, Russia, South Africa, and Türkiye and this positive effect probably resulted from loose environmental regulations in force during the study period. In conclusion, our findings support the validity of the fourth hypothesis of the study based on the associated literature.

Lastly, the effect of urbanization on CO<sub>2</sub> emissions can also be different depending on the EKC hypothesis and the positive effect of urbanization on CO<sub>2</sub> emissions can be negative at further economic development due to increasing economic activities with low emissions. Thus, Khoshnevis Yazdi and Dariani (2019), Aller et al. (2021), Amin et al. (2022), Luqman et al. (2023) and Arshad and Parveen (2024) uncovered a positive effect of urbanization on CO<sub>2</sub> emissions while Sharma (2011) uncovered a negative effect of urbanization on CO<sub>2</sub> emissions incompatible with these theoretical considerations. Our results also indicate that urbanization

| Table 10 Outcomes of JKS (2021) causality test. |                |                |
|-------------------------------------------------|----------------|----------------|
| HO hypothesis                                   | HPJ Wald test  | Test statistic |
| <b>BUS ⇌ CO2E.</b>                              | <b>7.5921</b>  | <b>0.0059</b>  |
| <b>CO2E ⇌ BUS.</b>                              | <b>15.8245</b> | <b>0.0001</b>  |
| <b>PROP ⇌ CO2E.</b>                             | <b>12.9583</b> | <b>0.0003</b>  |
| <b>CO2E ⇌ PROP.</b>                             | <b>56.9872</b> | <b>0.0000</b>  |
| ROL ⇌ CO2E.                                     | 0.0297         | 0.8631         |
| CO2E ⇌ ROL.                                     | 0.4664         | 0.4947         |
| <b>INCOME ⇌ CO2E.</b>                           | <b>5.5273</b>  | <b>0.0187</b>  |
| CO2E ⇌ INCOME.                                  | 1.7257         | 0.4219         |
| <b>URB ⇌ CO2E.</b>                              | <b>19.2395</b> | <b>0.0000</b>  |
| <b>CO2E ⇌ URB.</b>                              | <b>14.5407</b> | <b>0.0007</b>  |

Note: The bold rows show the statistically significant causal relationships between two series.

positively impacts CO<sub>2</sub> emissions in China, India, South Africa, and Türkiye. In a similar vein, loose environmental policies in these countries account for the positive interaction between urbanization and CO<sub>2</sub> emissions. In conclusion, our findings support the validity of the fifth hypothesis of the study based on the associated literature.

The causal nexus amongst CO<sub>2</sub> emissions, business regulations, property rights, rule of law, income, and urbanization is analyzed in the sample of BRICS-T for the 2000–2021 duration by way of the JKS (2021) causality test and the consequences of the test are demonstrated in Table 10. The results indicate a feedback interaction amongst business regulations, property rights, urbanization and CO<sub>2</sub> emissions and a unilateral causality from income to CO<sub>2</sub> emissions in the short term, but insignificant nexus between rule of law and CO<sub>2</sub> emissions.

The causal nexus amongst CO<sub>2</sub> emissions, business regulations, property rights, and rule of law only by Sezgin et al. (2024) and Viglioni et al. (2024). On the one hand, Sezgin et al. (2024) unveiled a bidirectional causality between business climate and CO<sub>2</sub> emissions. On the other hand, Viglioni et al. (2024) disclosed a bilateral causal interaction between property rights and CO<sub>2</sub> emissions. Therefore, the results of both Sezgin et al. (2024) and Viglioni et al. (2024) support our findings. Furthermore, a uni-directional causality from GDP per capita to CO<sub>2</sub> emissions uncovered by Wang et al. (2020) for central and eastern provinces of China, Topcu et al. (2016) and Balli et al. (2020) for Türkiye support our significant causality running from income to CO<sub>2</sub> emissions for the BRICS-T economies. Last, Khoshnevis Yazdi and Dariani (2019) revealed a bidirectional causal nexus between urbanization and CO<sub>2</sub> emissions in Asian countries similar to our results, but both Topcu et al. (2016) and Musa et al. (2021) respectively unveiled a unilateral causality from urbanization to CO<sub>2</sub> emissions for Türkiye and Nigeria.

Conclusion

CO<sub>2</sub> emissions have increased peculiarly as of the Industrial Revolution and negative environmental and health effects of growing CO<sub>2</sub> emissions have been noticed as of 1950s. In this context, the scholars have analyzed various institutional, socio-economic, and energy-related factors on CO<sub>2</sub> emissions in different countries and country groups. This article explores the nexus among CO<sub>2</sub> emissions, business regulations, property rights, rule of law, income, and urbanization in the BRICS-T economies through the novel causality and cointegration tests incompatible with the dataset’s characteristics considering the gap in the associated empirical literature.

The limitations of this study are as follows: First, the study sample includes only BRICS-T countries. Second, the study period is limited to the 2000–2021 period due to the availability of institutional and legal indicators. Third, the other external

variables except business regulations, property rights, legal system, income and urbanization which can impact CO<sub>2</sub> emissions have been disregarded.

The consequences of the JKS causality test demonstrate a feedback nexus between business regulations, property rights, urbanization, and CO<sub>2</sub> emissions. In other words, business regulations, property rights, and urbanization have a significant impact on CO<sub>2</sub> emissions. On the other hand, CO<sub>2</sub> emissions have a significant effect on business regulations, property rights, and urbanization. Furthermore, the results of cointegration test demonstrate that improvements in property rights decrease the CO<sub>2</sub> emissions at panel and in Brazil, China, and India and improvements in legal system decrease the CO<sub>2</sub> emissions in Brazil, China, India, South Africa, and Türkiye. However, increases in market-oriented business regulations, real GDP per capita, and urbanization have a positive effect on CO<sub>2</sub> emissions in most of the BRICS-T countries.

Based on our results and the related literature, market-oriented business regulations, income and urbanization positively impact CO<sub>2</sub> emissions in the BRICS-T countries and this effect mainly resulted from relatively looser environmental policies in force and current economic development levels of these countries. Therefore, these countries should balance the negative environmental effects of increasing economic activity by increasing the stringency of environmental policies through contemporary legal and market-based measures. Both well-defined property rights and an effectively functioning legal system are uncovered to be effective to decrease CO<sub>2</sub> emissions in the BRICS-T countries. Therefore, property rights and legal quality are significant tools to combat environmental problems. Future studies can research the effect of environmental policies on the nexus between institutional and legal indicators and CO<sub>2</sub> emissions.

Data availability

The dataset employed in the study can be accessed through Open Science Framework: <https://doi.org/10.17605/OSF.IO/2CN63>.

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### Author contributions

Idea/concept: YB, MUS, and YGG; data collection: YB and MUS; specification and implementation of methodology: YB, MUS, and YGG; discussion of the results: YB, MUS, and YGG; writing—review and editing: YB, MUS, and YGG. All authors read and approved the final article.

### Competing interests

The author declare no competing interests.

### Ethical approval

Ethical approval is not required because the study do not involve human participants.

### Informed consent

This article does not contain any studies with human participants performed by any of the authors.

### Additional information

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