A statistical examination of the link between environmental performance and legal practices: an evaluation of China's strategies for residual legislative power allocation

Ze-Hua Tian[1]*, Wu-Song Yang[2] and Cheng-Xue Tan[3]*

[1]Faculty of Law, Guangzhou College of Commerce, Guangzhou, China, [2]Faculty of Law, Guiyang College of Humanities and Technology, Guiyang, China, [3]Institute of Industrial Economics, Jinan University, Guangzhou, China

This study investigates the correlation between the environmental legal practices of different countries and their environmental performance. It entails an empirical analysis of cross-sectional environmental data collected from 34 countries, including members of the Organization for Economic Cooperation and Development (OECD) and the BRICs nations (Brazil, Russia, India, China, and South Africa). Then the study explores the correlation between a country's environmental performance and both the environmental policy stringency and regulatory enforcement. The findings from this global assessment are subsequently corroborated through an examination of China's environmental time series data spanning a decade, revealing a significant relationship between a country's environmental performance and regulatory enforcement. These results validate the Incomplete Law Theory within the field of environmental law. Moreover, as the second most populous and the third-largest country in terms of land area globally, China's environmental protection strategies and performance play a pivotal role in influencing international environmental outcomes. Consequently, the study conducts a case study on China's environmental legal practices and provides suggestions for enhancing China's allocation strategies of residual legislative power. The study advocates for the optimization of residual legislative power allocation within local environmental law enforcement agencies and a balanced distribution of public and private residual legislative power. This approach reinforces the government's role in strategic formulation.

KEYWORDS

environmental performance, environmental policy stringency, regulatory enforcement, residual legislative power, quantitative analysis, incomplete law theory

1 Introduction

In the past decade, the focus of environmental performance studies has shifted from predominantly economic and technological factors to a more holistic examination encompassing enterprise, government, and societal influences (Bhattarai, 2000; Anderson and Leal, 2001; Lahey and Doelle, 2012; Wang et al., 2015; Liu, 2021; Wang et al., 2021; Ha

et al., 2022; Yandle et al., 2022; Jaeger et al., 2023). Within the realm of economic factors, research on the interplay between economic development and environmental governance has frequently focused on the Environmental Kuznets Curve. This attests to the intricate relationship between economic dynamics and the levels of environmental governance (Bhattarai, 2000; Anderson and Leal, 2001; Yandle et al., 2002; Lahey and Doelle, 2012; Jaeger et al., 2023). On the technological front, concurrent studies have probed into how technological advancement shapes and influences environmental performance (Wang et al., 2015). Notably, ongoing investigations explore the impact of digitalization on a nation's environmental performance (Ha et al., 2022).

Turning to enterprise factors, recent scholarship has delved into the role and impact of corporate involvement in environmental governance, employing both quantitative and qualitative methodologies (Liu, 2021; Wang et al., 2021). Some studies have specifically examined the influence of the green finance pilot reform on corporate green innovation, using the formation of the China Green Finance Pilot Reform as a case study (Wang et al., 2023). From a governmental perspective, research exploring the intricate relationship between environmental performance and environmental governance is ongoing. Studies delve into the multifaceted role of government in environmental governance, considering aspects such as institutional characteristics, policy tools, objectives, and power dynamics (Dechezlepretre and Sato, 2017; Glicksman and Markell, 2018). Collaborative governance has emerged as a catalyst for enhancing environmental performance through innovation and resource availability (Wei, 2022). Ethical integration of environmental performance in public policies and private decision-making processes has proven effective (Messias et al., 2020), while the imposition of environmental taxes and stringent policies contributes to reduced pollutant emissions (Chen et al., 2022). In specific industries, such as the food sector, environmental regulations significantly influence environmental quality (Yang, 2022). Scholars are revisiting the theory and application of environmental information regulation, driven by growing investor interest in sustainability (Esty and Karpilow, 2019).

On the societal front, attention has turned towards Environment, Social, Governance (ESG) regulations and their impact on environmental performance (Tarmuji et al., 2016). However, scholarly research on the correlation between a nation's environmental performance and its environmental laws is notably scarce, particularly concerning China (Li et al., 2020). Examining specific issues in environmental law enforcement, current studies suggest that effective environmental performance can be achieved through a combination of inspection frequency and non-compliance penalties (Ma et al., 2021). Strict environmental regulations prompt companies to offset carbon emissions, a phenomenon amplified when companies face high legitimacy and efficiency pressures (Pan et al., 2022). Using the example of illegal wildlife crime in Kenya, research has scrutinized the role of environmental law in heightening environmental protection awareness and performance (Didarali et al., 2022).

Specifically, examining China's environmental performance and regulations is imperative given its pivotal role in advancing international environmental protection cooperation. This significance is underscored by China's status as the second most populous and the third-largest country in terms of land area globally (Sergeevna, 2015). In September 2020, China's General Secretary Xi Jinping introduced the "dual carbon" goals of "peaking carbon emissions" and achieving "carbon neutrality" during the 75th session of the United Nations General Assembly. In response to these ambitious goals, and to meet international commitments, Chinese government agencies at all levels have integrated environmental governance into critical governmental objectives. Consequently, environmental law, serving as an essential tool for "protecting and improving the environment, preventing pollution and other public hazards, safeguarding public health, promoting ecological civilization, and advancing sustainable economic and social development," (Article 1, Environmental Protection, 2015) assumes an enhanced role in strengthening China's environmental governance and environmental performance. Therefore, a legal examination of the relationship between a country's level of environmental performance and its domestic environmental legal practices is of paramount importance, offering valuable insights for subsequent legal and policy formulation and modifications.

So far, the impact of carbon emissions trading systems and regulations in China has been investigated. Research suggests that carbon trading systems significantly improve energy efficiency and environmental quality in regions with robust environmental law enforcement (Song et al., 2023). The enforcement of coal consumption constraint policy in China was found to reduce electrical energy efficiency in the pilot provinces, especially in provinces with weak law enforcement and small hydropower investment (Xu et al., 2022). The rule-of-law system in China still faces several challenges, such as inadequate legalization of industrial development, a mismatched supporting legal system, and outdated concepts and consciousness of circular economy legalization (Gao et al., 2023). Scholars have also focused on the role of guiding cases in enhancing environmental governance (Sun, 2022), dealing with environmental crimes (Zang, 2020; Liu and Wu, 2022), and conducting cost-benefit evaluations of environmental legislation (Gao, 2011).

Therefore, a noticeable void exists in the realm of quantitative analysis concerning the nexus between environmental performance and legal practices (Li et al., 2020). This paper endeavors to bridge this gap and contribute to future research by conducting an exhaustive examination of the correlation between environmental legal practices and environmental performance. Simultaneously, given China's standing as the second most populous and third-largest country globally, its environmental protection strategies and performance wield significant influence in shaping international environmental protection efforts. Consequently, utilizing China as a case study is paramount for understanding and dissecting relevant strategies and policies. This study aims to empirically explore the correlation between a country's environmental performance and the enactment and enforcement of its domestic environmental laws, utilizing environmental data from OECD and BRICs nations. Data is gathered from authoritative non-governmental organizations such as the OECD, World Bank official website, Yale Center for Environmental Law and Policy, and World Justice Project (WJP). The data primarily comprises the Environmental Performance Index, Environmental Policy Stringency Index, Rule of Law Index, and Gross Domestic Product (GDP) growth rate, Unemployment Rate (UR) and Consumer Price Index (CPI), all of which have been validated and used in numerous domestic and

international studies, attesting to their reliability and representativeness.

This study makes the following contributions. Firstly, while some prior studies have delved into the relationship between environmental performance and governmental policies (Ma et al., 2021; Didarali et al., 2022; Pan et al., 2022), fewer have focused on the consequential impact of environmental law, particularly its enforcement. In this context, the study uncovers the correlation between environmental performance and environmental law enforcement through meticulous data analysis. Furthermore, the study proposes actionable suggestions based on data analysis results to enhance strategies for residual legislative power allocation, offering valuable insights for policymakers. Secondly, from a theoretical standpoint, this study validates the Incomplete Law Theory within the field of environmental law and explores the evolution of environmental law enforcement following the tenets of this theory. Thirdly, this study takes a quantitative analysis approach, which enlarges relevant research perspectives and provides data foundation and support to legislature and enforcement organizations to make decisions. In detail, this study brings certain innovations in data collection and research perspectives. For instance, relevant data collection focuses on OECD and BRICs countries, which play important roles in improving international environmental performance. Besides, the variables and data collected from authoritative international organizations, academic institutions, and non-governmental organizations, providing stable and reliable data sources and significant reference value. All in all, the research findings hold profound implications for improving the environmental performance via environmental law, particularly in the context of China's "carbon peaking and carbon neutrality" goals and offer robust reference points for relevant government departments.

This study unfolds through six meticulously crafted chapters. In Chapter 2, we delve into the theoretical foundation that underpins and frames the entire study. Chapter 3 systematically unveils the experimental model and intricacies of the data utilized, providing a solid framework for the ensuing analyses. Chapter 4 takes a deep dive into the environmental data of OECD and BRICs countries, employing robust regression analysis to unearth the correlations between a nation's environmental performance and the intricate factors entwined with domestic environmental legal practices. Subsequently, this chapter rigorously validates the test results, extending its scrutiny to China's unique context, drawing from a decade's worth of environmental data. Chapter 5 proposes recommendations for the allocation of legislative powers in the field of environmental law by relevant Chinese government departments, guided by the "Incomplete Law Theory" based on the research findings. The final chapter offers research conclusions, summarizing key findings and insights derived from the analysis conducted throughout the study.

2 Theoretical foundation

Proposed in 2003 by Professors Pistor of Columbia Law School and Xu Chenggang of the London School of Economics and Political Science, the "Incomplete Law Theory" offers a fresh perspective on the ideal division of legal duties (Pistor and Xu, 2003). This theory revises the optimal deterrence model suggested by Bentham and Becker (Bentham and Dumont, 1830; Becker, 1968), which indicates that, under an ideally

constructed legal framework, courts would independently administer justice, eliminating the necessity for administrative law enforcement by regulatory bodies. Contrarily, the "Incomplete Law Theory" posits that due to inherent limitations, laws cannot be efficaciously enforced even with ample evidence (Pistor and Xu, 2003).

The theory underscores the dynamic interplay between the legislative, law enforcement, and judicial institutions concerning the allocation of residual legislative powers (Sun, 2005). Legislatures mainly operate proactively (ex-ante), judiciary primarily function re-actively (ex-post), while law enforcement agencies act as supplementary lawmakers, enforcing laws and playing pivotal roles both prior and subsequent to legislative enactments. The theory thereby highlights the integral role of regulators as adjunct legislators and proactive enforcers in exercising and implementing residual legislative powers (Huang and He, 2017; The Concept and Doctrine of Residual power, 2021). Furthermore, the design of enforcement agencies and the distribution of related powers are critical for societal goal attainment. Thus, regulators should continually adapt and formulate enforcement rules to account for shifts in socioeconomic, technological, and environmental landscapes.

Within this theoretical framework, a data analysis is crafted, exploring the relationship among environmental policy stringency, regulatory enforcement, and environmental performance. While existing research primarily focuses on the correlation between environmental policy stringency and pollution emission reduction (Chen et al., 2022), especially in CO2 emission reduction (Wolde-Rufael et al., 2021), this study aims to unveil more nuanced dynamics. Unlike previous research that delves into the inverted U-shaped relationship between pollution emissions and environmental policy stringency—depicting the time it takes for environmental policy stringency to manifest its effectiveness—our emphasis extends to comprehensively understanding the intricate interplay of these factors. Additionally, our study highlights the substantial influence of environmental law enforcement factors on environmental performance, aligning with the theory's emphasis on the pivotal role of regulators in exercising and fulfilling residual legislative powers.

As a result, the data analysis results derived from the "Incomplete Law Theory" hold profound significance for relevant government departments. These insights guide decision-making and offer crucial guidance to significantly enhance the nation's environmental performance levels.

3 Research design and data selection

In our study on the correlation between environmental performance and legal practices across different countries, we have adopted the research model proposed by Wolde-Rufael and Mulat-Weldemeskel (Wolde-Rufael et al., 2021). Utilizing cross-sectional data, the model is expressed as follows:

$$EPI_i = \alpha_0 + \alpha_1 EPS_i + \alpha_2 RE_i + \sum_{k=3}^{5} \alpha_k Controls_i + \varepsilon_i \qquad (1)$$

Here, the environmental performance (EPI) of a nation is presumed to be influenced by factors such as environmental policy stringency (EPS), regulatory enforcement (RE), and control variables denoted as "Controls," which include GDP growth (GGR), the unemployment rate (UR), and the consumer price index (CPI). In this model, "i" represents

TABLE 1 Definitions and descriptions of variables.

Variables	Sub-variables	Description
Environmental Performance (EPI)	Child mortality rate	Used as an indicator to measure the impact of environmental factors on health, reflecting conditions such as malaria, cholera, etc. It utilizes the mortality rate of children aged 1–5
	Air quality	Measures the impact of air quality on human health through the indoor and outdoor air pollution indices
	Air pollution	Utilizes *per capita* sulfur dioxide emissions and sulfur dioxide emissions per GDP unit as indicators to measure air pollution levels
	Water quality	Uses drinking water coverage rate and the number of sanitation facilities as indicators to measure the impact of water quality on human health
	Aquatic ecosystems	Indirectly measures the impact of industrialization on aquatic ecosystems by considering the changes in river water volume pre- and post-industrialization
	Biodiversity	Assesses a country's biodiversity through measures of biological community protection, key habitat conservation, and marine conservation
	Agriculture	Evaluates a country's level of agricultural environmental protection through agricultural subsidy situation and pesticide use management
	Forestry	Measures a country's level of forest conservation via forest growing stock and changes in forest cover rate
	Fisheries	Assesses a country's level of fishery conservation through the proportion of overfished or endangered fish species and fishing activities along the coastal continental shelf
	Climate change and energy	Measures a country's efforts in addressing climate change through *per capita* carbon dioxide emissions, carbon dioxide emissions per GDP unit, carbon dioxide emissions per kilowatt-hour, and the proportion of renewable energy resources
Environmental Policy Stringency (EPS)	Tax regulations	Evaluates the stringency of a country's environmental tax regulations through measures such as the carbon dioxide tax, diesel tax, nitrogen oxide tax, and sulfur oxide tax standards
	Trading rules	Measures the stringency of a country's environmental trading rules through parameters like carbon dioxide emissions trading, green certificate trading, and white certificate trading standards
	Grid electricity prices	Measures the level of support for renewable energy in a country's environmental laws through indicators such as wind power feed-in tariff subsidies and solar power feed-in tariff subsidies standards
	Emission standards	Assesses the stringency of a country's environmental laws on pollutant emissions through standards like nitrogen oxide emission limits, sulfur oxide emission limits, particulate matter (PM) emission limits, and diesel sulfur content limits
	Research and development subsidies	Measures the level of support for renewable energy development in a country's environmental laws through provisions for public research and development subsidies for renewable energy
Regulatory Enforcement (RE)	Enforce effectiveness	Measures the enforcement effectiveness of a country's government as an indicator of legal compliance
	Enforce without improper influence	Evaluates whether the enforcement of government regulations is unduly influenced by bribery or other private interests as an indicator of legal compliance in a country
	Enforce without unreasonable delay	Measures whether there are unreasonable delays in the enforcement procedures of national and local governments as an indicator of legal compliance in a country
	Due process	Assesses whether the administrative enforcement by national and local governments complies with the requirements of due process as an indicator of legal compliance in a country
	Lawful process expropriates	Measures whether the government avoids illegal expropriation of private property and provides sufficient compensation when property is lawfully taken, as an indicator of legal compliance in a country
Economic Development	GDP annual growth (GGR)	Quantifies the extent of GDP growth rate in various countries, serving as an indicator of their potential for national economic development
	Consumer price index (CPI)	Measures the average fluctuations in prices paid by consumers over time for a basket of goods and services in different countries, serving as an indicator of national economic conditions
	Unemployment rate (UR)	Quantifies the proportion of the labor force that is unemployed in various countries, providing an indicator of national economic conditions

TABLE 2 Descriptive statistics of the variables.

Variable	Mean	Median	Standard deviation	Minimum value	Maximum value	Kurtosis	Skewness
lnEPI	1.8295	1.8682	0.0970	1.4946	1.9429	5.6756	−1.6950
RE	0.6626	0.6700	0.1459	0.4100	0.8900	1.7595	−0.0457
EPS	2.5000	2.6313	0.9711	0.3750	3.8500	2.5995	−0.7302
lnGGR	0.5673	0.6419	0.9644	−1.6094	2.0669	2.7348	−0.5998
UR	9.0088	7.7500	5.55739	2.8000	24.8000	5.0067	1.6316
CPI	3.0491	2.5850	2.1348	−0.6900	9.4800	5.0845	1.2791

individual units of analysis, namely, countries, and α1 and α2 are the coefficients of primary interest.

To fortify the data analysis results of model (1), we employed panel data from BRICs countries and used the following model (2) for further robustness tests:

$$EPI_{it} = \alpha_0 + \alpha_1 EPS_{it} + \alpha_2 RE_{it} + \sum_{k=3}^{5} \alpha_k Controls_{it} + Year_t + \varepsilon_{it}$$

(2)

Here, "i" and "t" represent individual and time units, signifying countries and years, respectively. The inclusion of the "Yeart" variable accounts for temporal effects. Other indicators remain consistent with model (1).

Furthermore, to verify the correlation between environmental performance and regulatory enforcement specifically in China, we conducted additional regression tests using time series data of China.

To validate these assumptions and assess the impact of environmental policy stringency and regulatory enforcement on a nation's environmental performance, as shown in model (1), data from 34 nations, including OECD and BRICs countries, were gathered and analyzed. Specifically, the data included the Environmental Performance Index for EPI, Environmental Policy Stringency Index for EPS, Rule of Law Index for RE, GDP annual growth for GGR, total unemployment (modeled ILO estimate) for UR, and the Consumer Price Index for CPI. Additionally, panel data from BRICs countries between 2016 and 2020 were collected and analyzed according to model (2), to verify the cross-sectional data analysis results. Furthermore, data from China between 2010 and 2021 were specifically extracted for a localized examination.

Data sources include the Yale Center for Environmental Law and Policy for the Environmental Performance Index, the OECD for the Environmental Policy Stringency Index, and the WJP Project for the Rule of Law Index (RE). Data on GDP growth, the unemployment rate, and the consumer price index, sourced from the World Bank and IMF, were included to support the empirical analysis.

Table 1 below provides a detailed description of each variable and the corresponding sub-variables used in the study.

4 Empirical results

4.1 Cross-country evidence

The empirical analysis of this study encompasses 34 countries, including members of the OECD and BRICs nations. We utilized the

Stata software for conducting a comprehensive descriptive statistical analysis on the collected data. The analysis captures various critical variables, as displayed in Table 2:

Our analytical approach utilizes environmental performance as the dependent variable, with independent variables including regulatory enforcement, environmental policy stringency, GDP annual growth, unemployment rate, and the consumer price index. Employing Stata software, we conduct regression analysis using the least squares method, and the outcomes are presented in Column (1) of Table 3. Additionally, to validate the robustness of the cross-section data analysis results, we examine data from BRICs countries between 2016 and 2020. The results are presented in Column (2) and Column (3) of Table 3.

In the realm of cross-sectional data baseline regression analysis, our findings in Column (1) of Table 3 reveal that 84% of the variation in environmental performance can be attributed to a country's level of environmental policy stringency, the degree of regulatory enforcement, and economic development. Notably, the coefficient associated with regulatory enforcement-measuring the impact of regulatory enforcement on environmental performance-stands at 0.5383. The corresponding p-value is recorded at 0.007, demonstrating statistical significance at the 1% level and emphasizing its considerable importance.

Simultaneously, within the scope of robustness testing, Column (2) of Table 3 presents regression outcomes following the inclusion of year dummy variables and the application of robust standard errors. This analysis maintains the significantly positive coefficient related to regulatory enforcement, highlighting a positive correlation with environmental performance. Similarly, Column (3) of Table 3 incorporates year dummy variables and robust standard errors, exploring the interplay between regulatory enforcement and environmental policy stringency in relation to environmental performance. Once again, the results affirm the sustained significance of the regulatory enforcement coefficient, validating its positive association with environmental performance.

Both of these rigorous tests substantiate the substantial impact of law enforcement on the level of environmental governance and environmental performance. Their alignment with the baseline regression results attests to the robustness of the conclusions drawn in this article, reinforcing their validity. Furthermore, based on the Variance Inflation Factor (VIF) test presented in Table 4, the mean value of VIF is 3.1, significantly below the threshold of 10. This suggests that multicollinearity is not a significant issue in this regression analysis, instilling a reasonable degree of confidence in the reliability of the obtained results.

TABLE 3 Baseline regression and robustness testing.

	(1)	(2)	(3)
Variable	lnEPI	lnEPI	lnEPI
RE	0.5383***	5.1064*	3.7720**
	(0.1727)	(2.0306)	(2.4788)
EPS	−0.0131		−0.2167***
	(0.0201)		(−4.1228)
lnGGR	−0.0107	−0.3627***	−0.0675
	(0.0157)	(−4.8370)	(−0.8781)
UR	0.0015	−0.0288**	−0.0283***
	(0.0033)	(−2.7160)	(−4.8443)
CPI	−0.0118	−0.1203***	−0.0720***
	(0.0075)	(−3.9306)	(-3.0708)
Year	No	Yes	Yes
Constant	1.5063	3.1201**	3.5504***
	(0.1116)	(2.6906)	(5.0986)
R2	0.8370	0.8271	0.8998

Note: *、 **、 *** are commonly used symbols in statistical analysis to indicate the significance levels of 10%, 5%, and 1% respectively. The values within parentheses represent the standard errors.

TABLE 4 Results of multicollinearity test.

Variable	VIF	1/VIF
RE	5.60	0.1787
EPS	4.20	0.2379
lnGGR	1.92	0.5196
UR	1.30	0.7698
CPI	2.54	0.3941
Mean VIF	3.1	

In contrast to preceding studies, this research introduces a novel insight into the dynamics between environmental performance and environmental legal practices. While prior investigations predominantly delve into the connection between environmental policy stringency and pollution emission reduction, this study sheds light on the positive correlation between regulatory enforcement and environmental performance. Unlike pollution emission, the link between environmental policy stringency and overall environmental performance appears less clear and lacks statistical significance. One potential explanation is that in emerging legal frameworks, the existence and rigor of legislation wield substantial influence over environmental law. However, in nations with well-established environmental legislative systems, the degree of environmental policy stringency may no longer play a pivotal role in enhancing environmental performance. Additionally, countries with high environmental policy stringency might grapple with severe environmental challenges, potentially contributing to the absence of a statistically positive relationship.

This intriguing observation underscores the distinctive landscape of environmental law, diverging from other legal sectors (WHO, 2023 accessed). Nevertheless, it is evident that the enforcement of environmental policies and laws remains a paramount factor in environmental governance (Heyes, 2000). Given the current global emphasis on environmental issues like climate change, carbon emissions, and carbon trading, countries aspiring to enhance their environmental performance should prioritize robust enforcement of environmental laws. Such focus is likely to yield more significant impacts than merely raising environmental protection standards or implementing stringent regulations. Tangible improvements may involve enhancing the efficacy of law enforcement, minimizing interference, ensuring timeliness, and upholding procedural fairness within the realm of environmental law (WJP, 2022).

4.2 China case study

As the world's second most populous and third-largest country in terms of land area, China plays a crucial role in influencing international environmental performance through its environmental protection strategies. Therefore, it is imperative to examine China as a case study to understand its relevant strategies and policies.

This study aims to validate the association between China's environmental performance and its environmental legal practices. Following a methodology similar to the cross-sectional data analysis

TABLE 5 Descriptive statistics of the variables.

Variable	Mean	Median	Standard deviation	Minimum value	Maximum value	Kurtosis	Skewness
lnEPI	2.9923	3.1128	0.5513	2.2171	3.5822	1.4263	−0.2594
RE	0.3683	0.3750	0.0270	0.3312	0.3988	1.3150	−0.1885
EPS	1.0126	1.0314	0.0822	0.9035	1.1442	1.7626	−0.1540
lnGGR	0.8365	0.8572	0.1699	0.3424	1.0253	7.2976	−2.1315
CPI	2.4408	2.2450	1.1659	0.9800	5.5500	5.3683	1.5312

TABLE 6 Baseline regression and robustness testing.

	(1)	(2)
Variable	lnEPI	lnEPI
RE	13.4836**	11.4002**
	(3.8619)	(4.2831)
EPS	2.7198	2.5491
	(1.5122)	(1.6121)
lnGGR	0.2595	−1.1914
	(0.3608)	(1.2997)
CPI	0.1231	0.0320
	(0.0449)	(0.0490)
Constant	−4.9746***	−2.8172
	(1.2072)	(2.3834)
R2	0.9640	0.9647

Note: *, **, *** are commonly used symbols in statistical analysis to indicate the significance levels of 10%, 5%, and 1% respectively. The values within parentheses represent the standard errors.

of 34 countries, including members of the OECD and the BRICs nations, we apply the research model proposed by Wolde-Rufael and Mulat-Weldemeskel (2021). Relevant indices spanning from 2010 to 2021 were collected, enabling the construction of a time-series database to dissect the specific circumstances in China. Considering the contentious reliability of the unemployment rate in China (Wang, 2022), and the absence of a clear correlation—unlike studies in other nations where income inequality is commonly linked to the unemployment rate—introducing this variable into the forthcoming study, which exclusively focuses on China, appears unnecessary. Consequently, the unemployment rate variable has been excluded from the 'Controls' category, with its data integrated into the constant term within the model. The Stata software was employed to deliver the descriptive statistical results of the pertinent variables, which are encapsulated in Table 5.

The collected data served as the foundation for a regression analysis conducted using Stata software. This analysis positioned environmental performance as the dependent variable, while environmental policy stringency, regulatory enforcement, GDP annual growth, and the consumer price index served as independent variables. The Least Squares method was applied for this analysis, and the data analysis results are represented in Column

(1) of Table 6. Additionally, a robustness test involved regressing the data from 2010 to 2019, as presented in Column (2) of Table 6.

Our extensive data analysis highlights that China's environmental policy stringency, regulatory enforcement, and economic development collectively account for 96% of the variations in environmental performance. Interestingly, the strictness of environmental policy (p-value = 0.115) does not demonstrate statistically significant influences on environmental performance. However, regulatory enforcement emerges as a statistically significant factor impacting environmental performance at the 5% significance level (p-value = 0.010).

To further ensure the reliability of the results, the outcomes underwent scrutiny through the Breusch-Pagan/Cook-Weisberg test to investigate potential heteroscedasticity, as presented in Table 7.

To assess the quality of our regression model, we conducted the Breusch-Pagan/Cook-Weisberg heteroscedasticity test. This test evaluates the null hypothesis (H0) asserting constant variance (homoscedasticity) in the error term. With a test statistic of $chi2(1) = 0.57$ and a p-value = 0.4490, it fails to reject the null hypothesis at the 0.05 significance level. This result indicates that our model does not suffer from significant heteroscedasticity, satisfying one of the fundamental assumptions of linear regression models and reinforcing the reliability of our regression results.

TABLE 7 Results of the Breusch-Pagan/Cook-Weisberg heteroscedasticity test.

Test	Chi2	Prob > Chi2
Breusch-Pagan/Cook-Weisberg test	0.57	0.4490

Therefore, upon analyzing China's environmental performance, environmental policy stringency, regulatory enforcement, and economic development from 2010 to 2021, it can be deduced that a significant correlation exists with respect to regulatory enforcement, substantiated at the 5% significance level. These findings align with the insights gleaned from our analysis of data from various countries, offering mutual validation. Over the past 40 years, China's environmental legislation has matured, evolving into a system with distinct characteristics (Zheng and Wang, 2018; Zhuo et al., 2018; Ministry of Ecology and Environment, 2022). While environmental legislation appears to have entered a stage of stable development, the impact of regulatory enforcement on environmental performance is just beginning to manifest and strengthen progressively.

5 Analysis of the allocation of the residual legislative powers in China's environmental sector

By meticulously evaluating cross-sectional data from 34 nations and delving into environmental records from China over the past decade, this study upholds the relevance of the "Incomplete Law Theory" in the realm of environmental law. This theory highlights the essential role of regulators as adjunct legislators and proactive enforcers in exercising and implementing residual legislative powers (Huang and He, 2017; The Concept and Doctrine of Residual power, 2021). The analysis results affirm that the strictness of environmental legislation does not directly influence the levels of environmental performance, aligning with the theory's assertion of "Incomplete Law." Simultaneously, the marked impact of environmental law enforcement factors on environmental performance reinforces the theory's emphasis on the pivotal role of regulators in exercising and fulfilling residual legislative powers.

Therefore, it becomes imperative for relevant government departments to enhance the capabilities of environmental law enforcement agencies, guided by the principles of the "Incomplete Law theory". Empowering these agencies to effectively exercise and implement residual legislative powers can significantly elevate the nation's environmental performance levels.

5.1 Current allocation of residual legislative powers in China's environmental sector

The evolution of environmental legislative activities in China has gained significant momentum since the 1980s and continues to shape the country's environmental policies to this day. Over the last four decades, China's environmental legislation has been primarily influenced by major environmental incidents, governmental decisions, and the pressure to maintain a positive international reputation. These factors contribute to a complex landscape where the statistical correlation between environmental policy stringency

and environmental performance may not be straightforward. In nations with well-established environmental legislative systems, the degree of environmental policy stringency may no longer play a pivotal role in enhancing environmental performance.

The enactment of environmental laws, as exemplified by the environmental impact assessment system, along with the inception of unique environmental legal rules, collectively shape China's current environmental protection legal system. The structure of the present environmental legislative system in China is illustrated in Table 8 (Zheng and Wang, 2018).

Over the past four decades, there has been a steady increase in the prominence and effectiveness of environmental law enforcement agencies in China (Wang, 2017). The regulatory enforcement index of China has shown improvement, rising from 0.33 in 2010 to 0.39 in 2021, accompanied by a corresponding increase in the environmental performance index from 2.22 to 3.58. These positive developments highlight the progress made in environmental law enforcement. However, despite these advancements, there are still noticeable imbalances in the current allocation of environmental residual legislative power.

Firstly, there is an uneven distribution of residual legislative power among different law enforcement agencies. At a horizontal level, environmental protection requires a coordinated effort among multiple government departments, which often leads to fragmented and inefficient enforcement. The management of environmental pollutant emissions, for instance, suffers from an overlap in the issuance authorities of emission permits and fragmented management of multiple pollution sources, which impairs the effectiveness of pollution control (Zhao, 2017). Grassroots level enforcement also displays disarray, with numerous departments responsible for environmental law enforcement, leading to issues of overlapping authorities and work delays (Hu, 2018).

Secondly, an imbalance exists in the allocation of residual legislative power between public and private law enforcement domains. At the vertical level, environmental protection necessitates a balance between supervisory and accountability mechanisms among central and local law enforcement agencies. Currently, an excessive reliance on public authority in China's environmental law enforcement supervision mechanism has hindered the effective utilization of private law enforcement supervision mechanisms (Zhao, 2017). The potential of private supervision mechanisms, mainly driven by enterprises, remains largely untapped (Diao, 2016).

Lastly, the allocation of residual legislative power shows imbalances across different levels of authority. Contrary to the trend of decentralization in other administrative sectors, environmental law enforcement power in China exhibits an "upward flow", with powers being delegated to provincial and municipal levels to counter potential local protectionism (Gong and Lv, 2021; Government Administration Council of the Central People's Government, 2016). However, this strategy has neither resolved local protectionism issues nor empowered the county-level ecological and environmental departments with independent law enforcement authority, thereby limiting their effectiveness (Liu and Wu, 2022).

In summary, the present distribution of environmental residual legislative power in China exhibits marked imbalances, necessitating a thorough review and reformulation.

TABLE 8 Overview of representative Chinese environmental legislation documents.

Legislation category	Representative documents	Notes
Constitution	The Constitution of the People's Republic of China	Years of significant amendments: 1978, 1982, 2018
Laws	Environmental Impact Assessment Law; Environmental Protection Law	Specific area laws: Grassland Law; Forest Law; Water Pollution Prevention and Control Law; Air Pollution Prevention and Control Law; Marine Environmental Protection Law; Environmental Noise Pollution Control Law, etc.
Rules	Regulations on Environmental Impact Assessment for Planning	Specific area rules: Regulations on Nature Reserve; Regulations on Wildlife Protection; Regulations on Environmental Management of Construction Projects; Regulations on the Prevention and Control of Vessel-Generated Pollution in Waters, etc.
Standards	Administrative Measures for Ecological and Environmental Standards	There are currently over 1,000 specific national environmental protection standards in force

5.2 Exploring China's strategic approach to the allocation of environmental residual legislative powers

As highlighted in Section 5.1 and backed by documents such as the "Report of the Law Enforcement Inspection Team of the Standing Committee of the National People's Congress on Inspection of the Implementation of the Environmental Protection Law of the People's Republic of China" (The National People's Congress of the People's Republic of China, 2016), imbalances in power distribution among China's grassroots environmental law enforcement agencies and underdevelopment of private environmental law enforcement mechanisms present key challenges in the allocation of environmental residual legislative powers (Sun, 2018). Moreover, grassroots environmental law enforcement agencies in China often lack the necessary influence to execute their duties effectively, impeded by issues such as inadequate personnel training, lack of technical support, insufficient funding, and disjointed enforcement data (Cheng, 2012). In 2020, the score of due process in environmental administrative proceedings is as low as 0.39, which would be improved through better allocating environmental residual legislative powers to some extent.

In light of these challenges and taking into account the current state of environmental governance, the quantitative analysis of environmental law, and the theory of residual legislative power distribution, it becomes evident that the future of China's environmental law enforcement mechanism must pivot. The key areas of focus should be the optimization of residual legislative power distribution among grassroots environmental law enforcement agencies, and the pursuit of a balanced allocation of these powers between the public and private sectors.

5.2.1 Optimization of residual legislative power distribution among grassroots environmental law enforcement agencies

Optimization of residual legislative power distribution among grassroots environmental law enforcement agencies is of paramount importance. As discussed previously, the inherent "Incomplete Law" necessitates a dynamic approach where regulators continually update and establish enforcement rules, in response to shifting social, economic, technological, and environmental factors. In China's environmental sector, the emphasis should be on tilting the residual legislative power distribution towards local governments and fine-tuning the allocation of power among different departments.

On one hand, bolstering the distribution of residual legislative power to grassroots environmental law enforcement agencies, and promoting decentralized enforcement with independent authority, can rectify the issue of county-level ecological and environmental departments in China functioning merely as extensions of higher-level authorities, devoid of independent law enforcement capabilities. The existing strategy of consolidating environmental law enforcement powers at higher levels to counter local protectionism has shown limited effectiveness. As long as economic development continues to be the primary benchmark for local government assessments, environmental law enforcement agencies in China will grapple with limited motivation and pressure for strict enforcement (Ministry of Ecology and Environment, 2022). However, by amplifying regulatory powers at various levels and enhancing private enforcement and regulatory mechanisms, it is possible to curtail local protectionist tendencies of grassroots environmental law enforcement agencies and augment their effectiveness (Meng and Ma, 2017).

Simultaneously, there is a need to refine the distribution of residual legislative power among different departments within grassroots environmental law enforcement agencies. To address issues such as fragmented environmental law enforcement powers and unclear responsibilities among various local government departments, a consolidation of environmental law enforcement and promotion of interdepartmental collaboration can be highly effective. At present, a plethora of grassroots law enforcement departments in China, such as environmental protection bureaus, urban management bureaus, industry and information bureaus, public security bureaus, land bureaus, water bureaus, agriculture bureaus, market supervision bureaus, housing and construction bureaus, among others, wield environmental law enforcement powers. However, the division of environmental protection functions among these agencies remains nebulous. Therefore, exploring the refinement of power allocation rules to centralize environmental law enforcement powers under primary government departments, like the environmental protection bureau, while integrating environmental tasks with other administrative duties of various departments, is crucial.

Lastly, it's worth noting that amplifying the distribution of residual legislative power to grassroots environmental law enforcement agencies, promoting decentralized enforcement, and

optimizing power allocation among various departments, must be paired with the establishment of personnel certification and qualification management systems. This involves enhancing the professional competencies of environmental law enforcement personnel to holistically uplift environmental law enforcement effectiveness. To counter the issue of resource scarcity faced by these agencies, increasing technical and equipment investments in grassroots environmental protection law enforcement departments is essential.

5.2.2 Striving for balanced distribution of residual legislative powers between public and private sectors

While reinforcing the distribution of residual legislative power to grassroots environmental law enforcement agencies, China should actively foster mechanisms that fuse public and private enforcement of environmental law. Such an initiative could enhance its effectiveness and balance the distribution of residual legislative power between public and private sectors (Liu and Wang, 2011). The "supply chain law" mechanism presents an effective strategy in this context.

Currently, China's environmental law enforcement primarily hinges on reactive measures and lacks robust mechanisms for enterprise supervision. It falls short in continually monitoring corporate compliance with environmental protection obligations, relying predominantly on post-violation punitive measures for environmental regulation. The "supply chain law," a contemporary legislative model regulating multinational corporations' environmental obligations, offers instructive insights into its regulatory approach and content pertaining to corporate environmental obligations. The "supply chain law" typically mandates a legal due diligence duty upon relevant companies, requiring them to implement a series of measures ensuring stringent environmental protection obligations across their supply chains, including their own operations. These measures encompass risk analysis, internal accountability, preventive steps, and complaint management. Companies contravening relevant legal provisions could face hefty fines and may be barred from participating in government procurement projects for a stipulated duration (Tian, 2022).

Specifically, regarding environmental law enforcement, an expanded enforcement power could be granted to private entities. Drawing upon the legislative ethos of the "supply chain law," companies should be mandated to shoulder more environmental supervision responsibilities within their supply chain systems, and be endowed with the corresponding supervisory, preventative, accountability, and complaint handling authority. They should also be held responsible for reporting to local or higher-level environmental law enforcement agencies. This mechanism could prompt a shift in the distribution of residual legislative power towards private mechanisms, strike a balance between public and private distribution of residual legislative power, and enhance environmental law enforcement effectiveness in China, culminating in improved environmental governance across the nation.

6 Conclusion

This study aims to investigate the correlation between a country's environmental performance and its environmental legal practices. To address the existing gap in the literature regarding the relationship

between a country's environmental performance and environmental law enforcement, this study conducts an empirical analysis using cross-sectional environmental data collected from 34 countries, including members of the Organization for Economic Cooperation and Development (OECD) and the BRICs nations (Brazil, Russia, India, China, and South Africa). The analysis incorporates various factors such as the environmental performance index, environmental policy stringency index, regulatory enforcement index, and key economic variables like GDP annual growth, unemployment rate, and consumer price index. The empirical evidence gathered from this analysis strongly indicates a significant relationship between a country's environmental performance and the regulatory enforcement. However, the statistical relationship between a country's environmental performance and the stringency of its environmental policies remains unclear and requires further investigation.

To validate and reinforce the findings obtained from the global assessment, a subsequent examination of China's environmental time series data spanning a decade (2010–2021) was conducted. This analysis considered the same variables used in the broader study, including the environmental performance index, environmental policy stringency index, regulatory enforcement index, GDP annual growth, and consumer price index. The results highlight that while the intensity of China's environmental performance does not exhibit a significant correlation with the stringency of its environmental laws, it does show a substantial connection with the application and enforcement of these laws. Furthermore, the design of enforcement agencies and the distribution of related powers are critical for societal goal attainment.

Based on these findings, this study takes China as an example to analyze its environmental law legislation and enforcement situation in order to provide more detailed and practical suggestions. Specifically, the study highlights noticeable imbalances in the allocation of environmental residual legislative power in China. Firstly, there is an uneven distribution of residual legislative power among different law enforcement agencies. Secondly, there is an imbalance in the allocation of residual legislative power between public and private law enforcement domains. Lastly, the allocation of residual legislative power shows imbalances across different levels of authority. Therefore, the study advocates for optimizing the allocation of residual legislative power within local environmental law enforcement agencies in China and calls for a balanced distribution of public and private residual legislative power, reinforcing the role of the government in strategic formulation.

Due to limitations in data availability, the quantity of collected data for this study is somewhat restricted. Consequently, although the correlation between regulatory enforcement and environmental performance has been validated, there is still a need for further clarification regarding the extent of environmental policy stringency and its impact on environmental performance. To progress in this area, it is strongly recommended that relevant departments consistently examine the intricate interaction between environmental law and environmental performance. By doing so, they can establish a firm groundwork for continuously enhancing the rule of law in environmental affairs, not only within China but also globally. Moreover, future research should delve into exploring the specific influencing factors of regulatory enforcement that significantly affect a country's environmental performance.

Furthermore, it is crucial to elucidate the precise relationship between environmental policy stringency and environmental performance, along with their individual sub-variables. Conducting comprehensive analyses from both quantitative and qualitative perspectives would contribute significantly to the existing body of literature on this subject matter.

Publisher's note

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