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Industrial Structure Upgrading, Local Official's Promotion Pressure, and Green Total Factor Productivity: Evidence from China

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Abstract

The upgrading of industrial structure in China encourages the growth of emerging industries and the transformation of traditional industries, which contributes to high-quality economic development. Meanwhile, environmental regulation plays a key role in developing a green economy. However, the promotion pressure of local officials challenges environmental sustainability. The current study assesses green total factor productivity using the Global Malmquist–Luenberger index based on panel data of 30 provincial units in mainland China for the years 2005 to 2023 and investigates the link between industrial upgrading and green total factor productivity. Findings suggest that industrial structure upgrading significantly improves green total factor productivity. When environmental regulatory standards surpass a certain threshold, the positive impact of industrial constitution optimization on green total factor productivity diminishes. Overly strict environmental law rules may inhibit innovation investment and weaken technological transformation. Moreover, promotion pressure among local officials weakens the positive effect of industrial upgrading on green total factor productivity. China's political system has encouraged local officials to pay more attention to the development of secondary industries that have a significant impact on economic growth in the short term, often accompanied by depletion of natural resources and environmental damage. This paper offers a valuable reference for policy research in the development of sustainability in China.

Keywords: Sustainable development, promotion pressure, green total factor productivity, threshold effect

JEL Classification: L16, O44, P18

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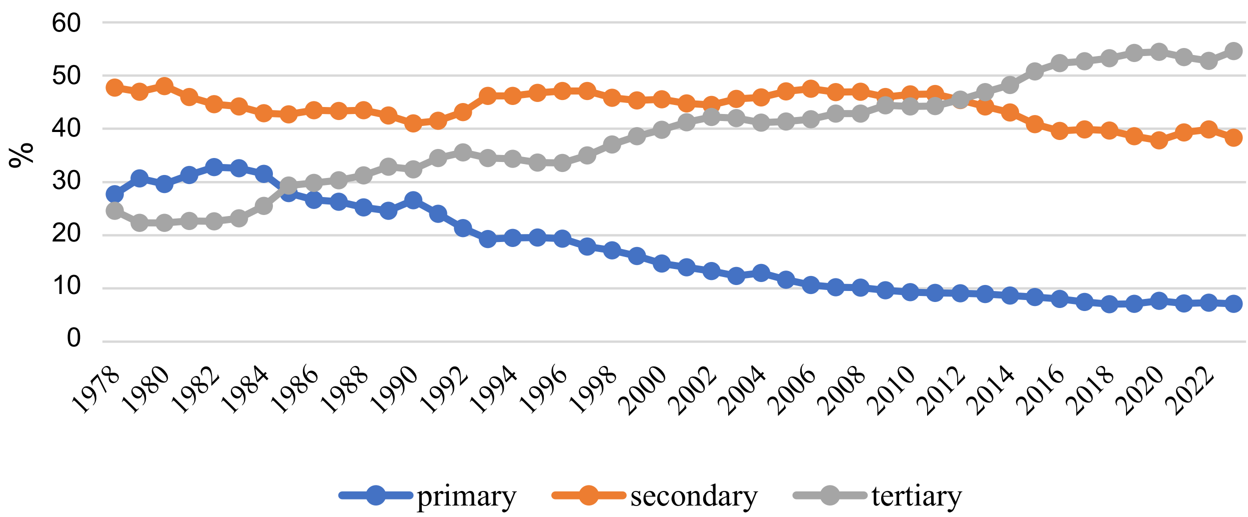
1. Introduction

Against the backdrop of escalating global climate change risks and tightening resource constraints, achieving the harmonious coexistence of economic growth and environmental protection has emerged as a central issue for the world (Hosan *et al*., 2022; Song and Zhang, 2022). The imperative for sustainable development has never been more urgent, as traditional industrial activities, particularly in sectors like chemicals, metallurgy, and coal, continue to be major contributors to environmental degradation, posing significant risks to long-term ecological viability (Xie and Bashir, 2024). While outright shutdowns of industrial and manufacturing sectors are not viable strategies for addressing pollution (Liu *et al*., 2025), the promotion of green transformation within economic sectors is recognized as a critical pathway to reconcile sustainable economic growth with environmental protection goals (Wang *et al*., 2025; Ameer *et al*., 2025). This global challenge underscores the necessity for economies to evolve towards more environmentally benign and resource-efficient structures.

Total Factor Productivity (TFP) has long been a significant indicator for assessing long-term economic development, revealing critical growth factors in firm-level and cross-national investigations (Dvouletý and Blažková, 2021; Lyu *et al*., 2023; Albulescu *et al*., 2025). However, a critical limitation of traditional TFP assessments is their failure to account for vital resources like energy and, more importantly, to incorporate environmental degradation factors. This omission leads to inaccurate evaluations of economic performance and an incomplete understanding of long-term growth dynamics (Sharma and Padhi, 2024; Xie *et al*., 2021). Consequently, Green Total Factor Productivity (*GTFP*), which explicitly integrates firms' energy use and pollution emissions, has emerged as an indispensable metric for charting sustainable development pathways and redefining national economic growth trajectories (Tong *et al*., 2022). *GTFP* offers a more comprehensive and precise analytical framework for evaluating the quality of economic development (Chen, 2010; Chung *et al*., 1997; Ramanathan, 2005). As nations increasingly prioritize the green economy, understanding how structural reforms, particularly industrial upgrading, can drive *GTFP* growth has become a central focus for both academia and policymakers.

As the world's largest developing country, China has experienced remarkable economic expansion over the past decades, with its unique political system playing a pivotal role (Ge and Liu, 2022). However, this rapid growth has been largely driven by a traditional extensive growth model, leading to severe environmental issues, including low energy efficiency and excessive pollutant emissions, which now pose significant bottlenecks to sustainable economic development (Bai and Nie, 2018). To address this, China's 13th Five-Year Plan explicitly prioritized the green economy, and the 14th Five-Year Plan further emphasized the importance of low-carbon transformation and sustainable industrial upgrading. Against this backdrop, industrial structure upgrading, known as a critical path of transforming the economic development model, requires an in-depth study of its impact on *GTFP*. Statistical data, as shown in Figure 1, reveal significant changes in China's industrial structure: the share of primary industry in GDP dropped from 27.7% in 1978 to 7.1% in 2023; the secondary industry's share accelerated its decline after 2012, and dropped to 38.3% in 2023; and the tertiary industry's share exceeded that of the secondary industry for the first time in 2012 (45.5%), rising to 54.5% in 2023, indicating a shift from "industry-led" to "service-led" development. Given these profound structural shifts and policy directives, critical questions emerge: Has this structural change effectively promoted *GTFP*? And crucially, how does China's unique political system, particularly the incentives for local officials, influence this process? Addressing these questions is not only theoretically significant but also holds immense practical importance for achieving China's ambitious "double carbon" goals.

Figure 1: The proportion of industries to GDP in China, 1978 to 2023



Source: Authors' own elaboration

To this end, we conducted a panel data survey spanning 2005 to 2023, and we focused on the provincial administrative units of China for two reasons. First, China is undergoing the largest and fastest industrial structural transformation in human history. Its ongoing transformative experience offers invaluable insights for other developing countries navigating similar transitions toward sustainable development. Second, China's provincial officials, second only to central authorities in the political hierarchy, wield substantial authority within their jurisdictions. Crucially, China's unique political system, characterized by a "promotion tournament" where local officials' career advancement is often tied to GDP growth, endows them with significant economic intervention capabilities. This system frequently leads officials to prioritize short-term economic gains, often neglecting emerging industries and services that require long-term investment but yield substantial environmental benefits. This inherent conflict between political incentives and environmental goals makes China an exceptionally unique and pertinent case for studying how political intervention moderates the relationship between industrial upgrading and environmental efficiency. Therefore, selecting China as the research sample is justified not only by its representativeness as a large developing country in transition but also by the unparalleled institutional context provided by its political system, which allows for research findings with both profound theoretical depth and practical relevance.

This work makes several significant contributions to the existing literature. First, it measures China's provincial *GTFP* from 2005 to 2023 using the Global Malmquist–Luenberger Index (GMI) with non-desirable outputs, a method that more comprehensively captures productivity changes under environmental constraints compared to traditional approaches. Second, it innovatively introduces environmental regulation intensity as a threshold variable to construct a nonlinear econometric model. This approach allows for the identification of stage-specific characteristics of industrial structure upgrading's impact on *GTFP*, revealing nuanced relationships that linear models might overlook and offering critical insights for policy design. Third, it uniquely incorporates local official promotion competition into the analytical framework to examine how political incentives moderate the relationship between industrial upgrading and green efficiency. This integration addresses a crucial gap in understanding the interplay between political governance and environmental outcomes in a transitional economy like China. By comprehensively integrating economic structural change, the effects of policy tools, and the characteristics of political governance, this work provides targeted theoretical insights and practical implications for industrial policy design, particularly in the context of China's ambitious "double carbon" goals ("Carbon Peak" and "Carbon Neutrality").

The remaining parts of this paper are arranged as follows: Section 2 provides a review of previous research by focusing the discussion on the relationships between variables, and develops research hypotheses. Section 3 discusses data sources, the variables of interest, and the econometric models. Research findings are presented in Section 4, while Section 5 concludes.

2. Literature Review and Hypothesis Development

2.1 Literature review

Krugman (1994) argued that TFP reflects the progress of technology and efficiency. Although TFP can measure the efficiency of shifting economic growth from an extensive to an intensive model, traditional TFP is insufficient to comprehensively and accurately assess the quality of economic development under increasingly severe resource and environmental constraints (Han *et al*., 2022). *GTFP*, emphasizing environmental protection and efficient resource use, primarily stems from green technological progress and efficiency improvements. *GTFP* evaluation indicators incorporate input factors such as capital, labor, and energy, as well as desirable outputs (*e.g.*, GDP) and undesirable outputs such as wastewater, exhaust gas, waste, and carbon dioxide (Elsadig and Ahmed, 2012). Fukuyama and Weber (2009) developed a non-radial, non-oriented SBM directional distance function derived from the slack-based measure (SBM) model to measure *GTFP*. Xia and Xu (2020) incorporated environmental performance variables into a production model and employed data envelopment analysis (DEA), a non-parametric method, to evaluate regional *GTFP* in China.

Industrial structure upgrading is typically characterized by changes in the proportion of the three industrial sectors and the transformation within each industry toward high-value-added and low-pollution links (Gan *et al*., 2011). In empirical research, scholars measure industrial structure upgrading through two main approaches: one uses the ratio of tertiary to secondary industry value added (Zhang *et al*., 2024) to assess the transition from industry-led to service-led economies; the other constructs comprehensive indicators including dimensions such as technological density and environmental efficiency, for example, incorporating the proportion of high-tech manufacturing and producer services (Ke and Yu, 2024). Existing studies generally agree that industrial structure upgrading enhances *GTFP* through technological innovation and resource reallocation. Pai (2016), Tu and Chen (2019), and Lu and Zhao (2020) highlighted that industrial structure optimization positively influences TFP. He and Shen (2018) argued that industrial upgrading and increased technological innovation contribute to enhancing TFP. Zhang (2020) suggested that promoting industrial structure upgrading can improve total factor productivity in urban agglomerations. Yin *et al*. (2020), using an extended vector autoregressive model, found that industrial structure advancement positively impacts total factor productivity across different economic periods. Yang and Jiang (2021) identified industrial structure upgrading as a channel through which the digital economy influences total factor productivity.

Under China's institutional arrangement of political centralization and local decentralization, local government officials significantly impact regional economic development.

Meanwhile, motivated by promotion incentives, local officials intensify competition among local governments (Zhou and Tao, 2011). Xu *et al*. (2007) noted that Chinese local officials play active roles in economic development. In the process of developing regional economies, Zhou (2004) emphasized that under the promotion tournament mechanism, superior officials primarily evaluate and promote subordinate officials based on economic growth indicators (*e.g.*, GDP growth rate), incentivizing subordinates to pursue economic development for political advancement. To achieve short-term growth, local officials tend to support large-scale, quick-return manufacturing industries (especially heavy industry), potentially exacerbating overcapacity and environmental pollution (You *et al*., 2019). Qiao (2013) validated the existence of this promotion tournament mechanism through a moral hazard model. Cole *et al*. (2009) argued that local officials may lower environmental standards during competition to attract investment, leading to more "high-pollution, high-emission, high-energy consumption" enterprises settling locally, which exacerbates environmental issues. Zhang *et al*. (2017), using a logit model on official promotion, found that local government officials' pursuit of promotion contributed to regional environmental degradation during China's industrialization.

Existing literature generally acknowledges that industrial structure upgrading positively impacts *GTFP* through channels such as technological innovation and resource reallocation (Zhu *et al*., 2022; Liu *et al*., 2022; J. Sun *et al*., 2022). For example, Y. Sun and S. Sun (2014) argued that the transformation of industrial structure toward high-value-added sectors reduces environmental burdens through intensive production models, thereby enhancing green economic efficiency. Despite these insights, significant research gaps persist, particularly within the unique context of China. First, the crucial moderating role of local official promotion competition, embedded within China's distinctive political governance framework, on the relationship between industrial upgrading and *GTFP* remains largely unexplored. Under a GDP-centered evaluation mechanism, local governments, driven by political incentives, often prioritize short-term economic growth, which can complicate the effective enforcement of environmental regulations and distort the direction of industrial transformation (Wu *et al*., 2013; Wang and Xu, 2010). Second, the non-linear impact of the interaction between environmental regulation, a key policy tool linking industrial structure and green development, and industrial upgrading on *GTFP* requires further systematic clarification. While moderate environmental regulation may stimulate industrial technological innovation, overly stringent regulations could potentially stifle enterprise vitality, yet this threshold effect remains untested systematically. Building upon this gap, this paper empirically investigates the nonlinear relationship between industrial upgrading and *GTFP*, with environmental regulation intensity serving as a threshold variable, and by developing an index of officials' promotion pressure to examine its moderating effect.

2.2 Hypothesis development

Industrial system upgrading is a crucial driver of economic growth, acting as a resource converter and pollutant control body (Yu, 2017). It shapes the trajectory of economic development while simultaneously enhancing *GTFP* (Timmer and Szirmai, 2000; Bosworth *et al*., 2008; Chen and Wang, 2021). The transition from old to fresh industries has led to the emergence of cleaner and more efficient sectors, fostering better resource allocation and production efficiency across society (Han *et al*., 2019). To achieve carbon neutrality, China has established a three-party synergy between industry, the economy, and the environment, resulting in a notable enhancement of *GTFP* (Ke and Zhao, 2014). Further, the implementation of environmental regulations has spurred the development of a more robust incentive system for green technology innovation (Feng *et al*., 2017; Cai and Zhou, 2017). According to Xu and Yin (2021), environmental regulations can stimulate technological innovation in enterprises, leading to both financial gains and the mitigation of environmental governance expenses.

Additionally, previous research has demonstrated the positive effects of environmental regulation on enhancing *GTFP* within specific sectors including manufacturing, the chemical industry, and thermal power (Xu *et al*., 2022; Dong and Xie, 2022). However, there are conflicting findings which suggest that environmental regulations might impede *GTFP*. This is because regulations elevate the costs associated with environmental governance, potentially crowding out productive investments, and thereby exerting a detrimental effect on *GTFP* (Yuan and Xiang, 2018). A study by Zhou *et al*. (2021) revealed that heightened environmental regulations resulted in increased pollution control costs rather than in fostering technological innovation, ultimately leading to a reduction in total factor productivity.

China's official governance system is characterized by a hierarchical structure where lower-level officials' evaluations and promotions are directly influenced by their superiors. Due to the limitation of the number of tenure positions, local officials who are placed in the administrative hierarchy would prioritize their career advancements over sustainable development (Maskin *et al*., 2000; Sang and Yan, 2014). Research findings by Li and Zhou (2005) suggest that strong economic performance can significantly boost local officials' chances of promotion. The study by Xu and Wang *et al*. (2010) further supports this finding, indicating that local officials are more likely to prioritize economic growth when faced with political incentives. Following China's economic reforms and opening up of the economy, a promotion evaluation system centered around GDP has been implemented (Zhou, 2007). Driven by promotion incentives, local officials often prioritize economic growth at the expense of the environment. Zhong and Wang (2010) highlighted that the decision-making of local officials negatively impacts local energy efficiency while increasing economic growth. Despite the recognition of environmental concerns, local officials who are motivated by promotion prospects have relaxed environmental protection standards in order to attract foreign investments (Chen, 2009). Additionally, in their efforts to compete with more prosperous regions, local governments that are located in less developed regions have greater incentives to lower environmental protection standards (Li, 2009).

In view of this, the current study proposes the following three research hypotheses.

H_1: Industrial system upgrading has a favorable influence on *GTFP*.

H_2: The marginal effect of industrial constitution optimization in improving *GTFP* decreases as the stringency of environmental regulation increases.

H_3: The beneficial influence of industrial optimization on *GTFP* is undermined by the promotion pressure experienced by local officials.

3. Methodology

3.1 Research variables

Green Total Factor Productivity: Following Tone and Sahoo (2003), we measure *GTFP* by constructing an evaluation indicator that incorporates input, desirable output, and undesirable output (see Table 1). Subsequently, the Global Malmquist–Luenberger (GML) index is calculated using the Slack Based Measure model of super efficiency (see Equation (1)). Consistent with the methodology of Feng and Zhang (2017), *GTFP* is then derived from the GML.

$$\rho = min \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^x}{x_{i0}}}{1-\frac{1}{s_1+s_2}(\sum_{k=1}^{s_1}\frac{s_k^y}{y_{k0}}+\sum_{l=1}^{s_2}\frac{s_l^z}{z_{l0}})}$$

$$\text{s.t.}\begin{cases} x_{i0} \geq \sum_{j=1,j\neq 0}^{n}\lambda_j x_j - s_i^x, \forall i; \\ y_{k0} \leq \sum_{j=1,j\neq 0}^{n}\lambda_j y_j + s_k^y, \forall k; \\ z_{l0} \geq \sum_{j=1,j\neq 0}^{n}\lambda_j z_j - s_l^z, \forall l; \\ 1 - -\frac{1}{s_1+s_2}(\sum_{k=1}^{s_1}\frac{s_k^y}{y_{k0}} + \sum_{l=1}^{s_2}\frac{s_l^z}{z_{l0}}) > 0; \\ s_i^x \geq 0, s_k^y \geq 0, s_l^z \geq 0, \forall i,j,k,l \end{cases} \tag{1}$$

where ρ is the efficiency value of the decision-making unit (DMU). Specifically, m, s_1 and s_1 represent the number of each DMU; λ is the strength vector and x_{i0}, y_{k0} and z_{l0} are the column vector of input, desirable output, and undesirable output; s_i^x, s_k^y and s_l^z are slack variables.

Table 1: Evaluation Index of *GTFP*

Indicator Type	Variable	Code	Definition
Input	Capital input	*Capital*	Real capital stock
	Labor force input	*Labor*	Number of employed populations
	Energy input	*Energy*	Energy consumption
Desirable output	Gross Domestic Product	*GDP*	Real GDP based on 2004
Undesirable output	Chemical oxygen demand	*COD*	Chemical oxygen demand levels in wastewater from industrial processes
	Exhaust emission	*SO2*	emissions of SO2 from industrial exhaust gases

Source: Authors' own elaboration

Subsequently, we calculated the mean of *GTFP* by province and by year, as presented in Figure 2 and **Chyba! Nenalezen zdroj odkazů.**. Figure 2 illustrates that *GTFP* in China exhibited a continuous upward trend from 2005 to 2023, culminating in a peak value of 3.291 in 2023. Table 2 highlights significant provincial disparities in *GTFP*, with Shandong (4.647) registering the highest *GTFP*, followed by Chongqing (3.747) and Beijing (3.595). Notably, certain provinces recorded *GTFP* indices of less than 1, such as Xinjiang (0.953), Hainan (0.901), Shanxi (0.848), Guangxi (0.829), and Guizhou (0.655). Moreover, we further investigated the spatial characteristics of *GTFP* by generating spatial distribution maps for selected years (2005, 2009, 2013, and 2018) based on the data from Table 2 (see Source: Authors' own elaboration

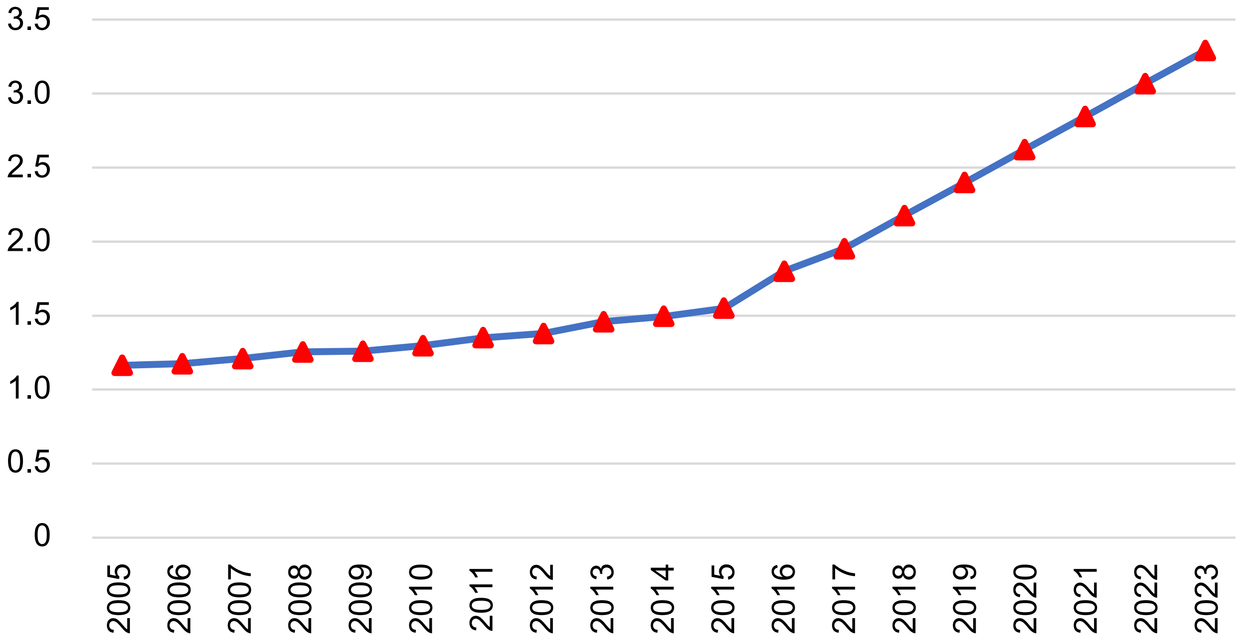
Figure 3). The colour intensity reflects the *GTFP* index, where darker shades indicate higher magnitudes. Figure 3 reveals that provinces with higher *GTFP* values are predominantly concentrated in the economically developed eastern regions, whereas lower *GTFP* indices are primarily observed in the western regions.

Table 2: Average of *GTFP*, 2005-2023

Region	*GTFP*	Region	*GTFP*	Region	*GTFP*	Region	*GTFP*	Region	*GTFP*
Shandong	4.647	Shanghai	2.600	Hunan	1.488	Henan	1.390	Ningxia	1.143
Chongqing	3.747	Sichuan	2.335	Hubei	1.464	Heilongjiang	1.388	Xinjiang	0.953
Beijing	3.595	Hebei	2.170	Zhejiang	1.460	Yunnan	1.276	Hainan	0.901
Guangdong	3.257	Fujian	1.640	Gansu	1.409	Jiangxi	1.224	Shanxi	0.848
Jiangsu	3.118	Neimenggu	1.522	Shaanxi	1.400	Anhui	1.207	Guangxi	0.829
Tianjin	3.091	Liaoning	1.514	Qinghai	1.399	Jilin	1.186	Guizhou	0.655

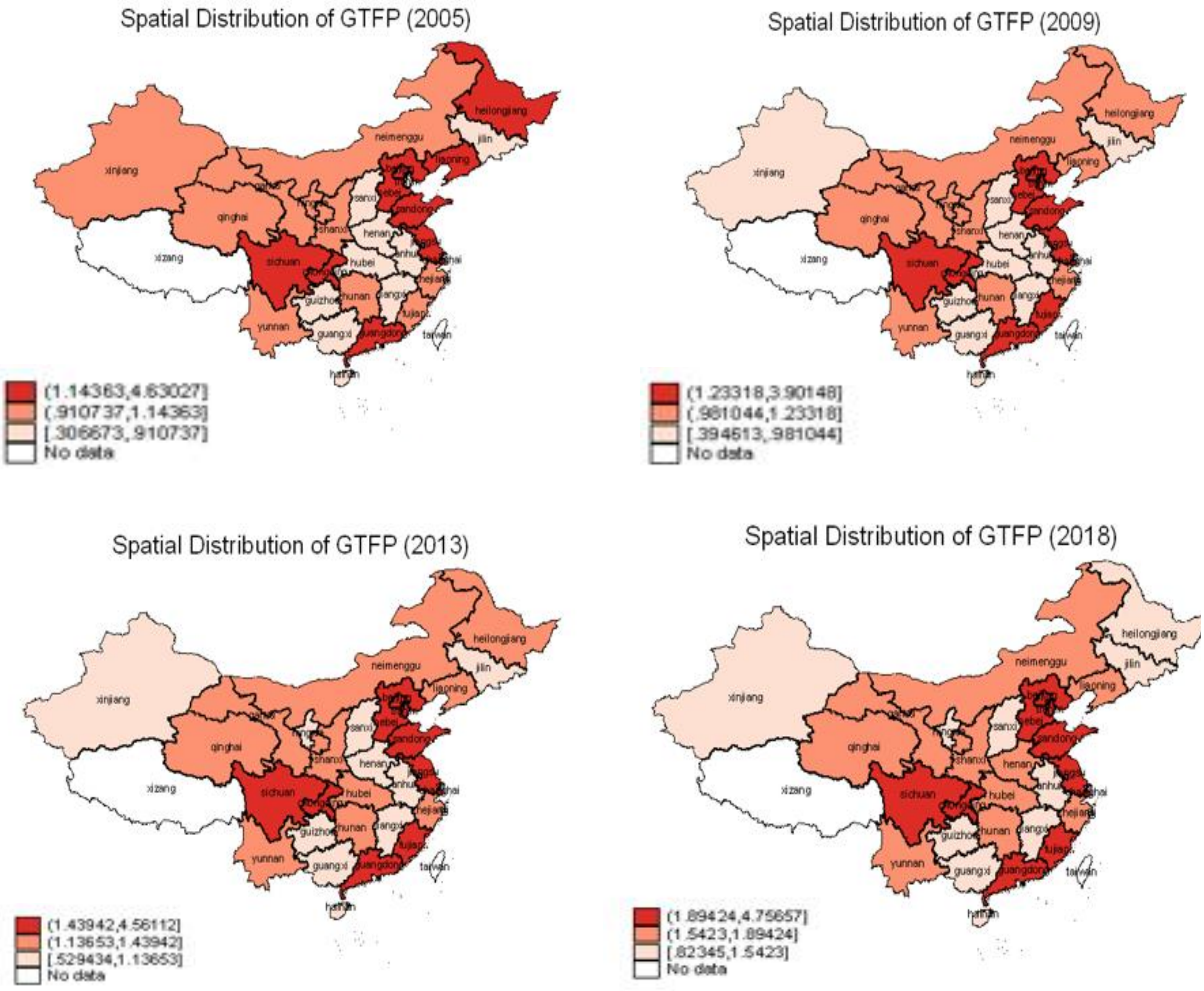
Source: Authors' own calculations

Figure 2: The *GTFP* of China from 2005 to 2023



Source: Authors' own elaboration

Figure 3: Spatial Distribution of *GTFP*, 2005, 2009, 2013, 2018



Source: Authors' own elaboration

Industrial structure upgrading: The variable industrial structure upgrading (*ISU*) is measured as the proportion of the tertiary sector yield to the secondary sector output (see Wang *et al*., 2020).

Promotion pressure on local officials: Following Qian *et al*. (2011), we develop the variable promotion pressure (*PRESSURE*) using the GDP growth rate, fiscal surplus, and unemployment rate. First, fiscal surplus and unemployment rates are calculated as per Equations (2) and (3). Second, the weighted averages of fiscal surplus and the unemployment rates are determined, with GDP serving as the weighting factor. Subsequently, we construct the promotion pressure index according to the following rules: If the GDP growth rate is below its average value, it is assigned a score of 1, otherwise, the score is 0. A similar scoring method is applied to fiscal surplus. If the unemployment rate exceeds its average value, it is given a score of 1, otherwise, it is 0. Finally, a total score is derived by summing the scores of the three factors, thereby yielding a promotion pressure index ranging from 0 to 3. A higher score indicates stronger promotion pressure faced by local officials.

$$Y = \frac{Y_1 - Y_2}{Y_1} \tag{2}$$

$$Z = \frac{Z_1}{Z_1 + Z_2} \tag{3}$$

where Y is fiscal surplus; Y_1 is fiscal revenue; Y_2 is financial expenditure; Z is unemployment rate; Z_1 is unemployed population; and Z_2 is employed population.

Environmental regulation: Environmental regulation (*ER*) is calculated as the ratio of expenditure on industrial pollution control to the yield of the secondary industry (see Liu and He (2021)).

Additionally, we incorporate several control variables that may affect *GTFP*: trade liberalization intensity (*OPEN*), measured as the proportion of international trade to GDP; human capital (*HC*), calculated as the ratio of individuals enrolled in higher education institutions to the total population; financial development level (*FIN*), gauged by the ratio of loans outstanding to GDP at year-end; economic level (*PERGDP*), measured at per capita GDP; and marketization level (*MAR*), indicated by marketization index (see Wang *et al*., 2021; Tian and Hu, 2023; Yang and Wang, 2018).

3.2 Sample and data

The sample used in the current analysis is sourced from the provincial entities in mainland China for the years 2005 to 2023, excluding data for Tibet. Data are obtained from the China Statistical Yearbook, the Provincial Statistical Yearbook, and the China Marketization Index database. Table 3 reports the descriptive statistics of variables used in the current study.

Table 3: Descriptive Statistics

Variable	Observation	Minimum	Mean	p50	Maximum	Std.
GTFP	570	0.307	1.829	1.383	8.447	1.381
ISU	570	0.527	1.280	1.132	5.447	0.715
OPEN	570	0.0109	0.303	0.146	1.711	0.347
HC	570	6.550	9.026	8.951	12.87	1.018
FIN	570	0.589	1.355	1.264	2.613	0.452
PERGDP	570	5218	49855	42326	224912	34662
MAR	570	3.360	7.855	7.970	12.13	1.896
PRESSURE	570	0	1.796	2	3	0.841
ER	570	0.00004	0.0035	0.0027	0.0245	0.0031

Note: p50 means Median; Std. is Standard deviation.
Source: Authors' own calculations

3.3 Econometric model

To test hypothesis H_1, we employ $GTFP$ as the dependent variable and the optimization of the industrial framework as the independent variable, thereby constructing the following baseline model presented in Equation (4).

$$GTFP_{i,t} = \alpha_0 + \alpha_1 ISU_{i,t} + \theta \boldsymbol{X}_{i,t} + \varepsilon_{i,t} \tag{4}$$

where i is the provincial unit; t is the time dimension; $\boldsymbol{X}$ is a vector representing control variables; α_0 is the intercept term; α_1 and θ are regression coefficients, and $\varepsilon_{i,t}$ is a random disturbance term.

Furthermore, following Hansen (1999), we investigate the threshold effect of industrial framework upgrading, with environmental regulation as the threshold variable. Equation (5) shows the empirical threshold model.

$$\begin{aligned} GTFP_{i,t} &= \beta_0 + \beta_1 ISU_{i,t}(ER_{it} \leq \gamma_1) + \beta_2 ISU_{i,t}(\gamma_1 < ER_{it} \leq \gamma_2) + \cdots + \\ &\beta_n ISU_{i,t}(\gamma_n < ER_{it} \leq \gamma_{n+1}) + \beta_{n+1} ISU_{i,t}(ER_{it} > \gamma_{n+1}) + \theta X_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

where ER is the threshold variable; and γ is the threshold value.

Given that local officials' promotion pressure may weaken the relationship between ISU and $GTFP$, an interaction term is introduced in the baseline model to test hypothesis H_3, as shown in Equation (6).

$$GTFP_{i,t} = \alpha_0 + \alpha_1 ISU_{i,t} + \alpha_2 PRESSURE_{i,t} + \alpha_3 ISU_{i,t} \times PRESSURE_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \quad (6)$$

where *PRESSURE* is the promotion pressure index, and the coefficient (α_3) of the interaction term $ISU_{i,t} \times PRESSURE_{i,t}$ is used to investigate a moderation effect.

4. Results and Discussion

To mitigate the issues of multicollinearity and heteroscedasticity within the model, we apply a natural logarithm transformation to all continuous variables. All regression analyses are performed using the statistical software Stata.

4.1 Benchmark model

Table 4 presents the estimation results of the benchmark model (Equation (4)). Columns (1), (2), and (3) represent the outcomes of the regressions using pooled ordinary least squares (POLS), random effects (RE), and fixed effects (FE) respectively. In column (1), the coefficient of *ISU* is 0.1574, statistically significant and positive at the 1% level. In column (2) and column (3), the coefficients of *ISU* are 0.3998 and 0.4270, respectively, both statistically significant at the 5% level. These findings suggest that *ISU* contributes to the increments in *GTFP*. Thus, hypothesis H1 is supported by the results obtained.

Furthermore, the Hausman test indicates that the FE model is preferred over POLS and RE. Therefore, we adopt the FE method in subsequent empirical estimations.

Table 4: Regression Results of Benchmark Model

	(1)	(2)	(3)
	POLS	**RE**	**FE**
ISU	0.1574*** (0.0559)	0.3998** (0.1598)	0.4270** (0.1684)
OPEN	0.0677*** (0.0204)	0.0043 (0.0550)	−0.0147 (0.0689)
HC	−1.0649*** (0.2633)	−0.7057 (0.7400)	−0.6811 (0.7619)
FIN	−0.1122 (0.0731)	−0.1412 (0.1859)	−0.1395 (0.1918)
PERGDP	0.5033*** (0.0473)	0.4515*** (0.1105)	0.4471*** (0.1122)
MAR	0.5682*** (0.0921)	0.1551 (0.2319)	0.0860 (0.2491)
Constant	−3.6128*** (0.4344)	−3.1508*** (0.8619)	−3.0548*** (0.8962)
Observations	570	570	570
R^2	0.5589	0.7024	0.7030
F-statistic	99.3654***		38.1585***
Hausman	21.32 (p = 0.0000)		

Notes: Standard errors are in parentheses. *, **, *** denote statistical significance at 10%, 5%, and 1% levels, respectively. *GTFP* stands for the dependent variable.

Source: Authors' own calculations

4.2 Robustness tests

Robustness tests are performed by running sensitivity tests in three ways. First, we calculate the optimization of the industrial framework using Equation (7) (see Liao and Gong, 2020). Second, we add a control variable, namely the level of infrastructure (INF), which is measured as the ratio of total highway mileage to land area of each province. Then, we use the Generalized Method of Moments GMM to estimate Equation (4) instead of using the FE method. GMM comprises the methodologies known as the Difference Generalized Method of Moments (DIF-GMM) and the System Generalized Method of Moments (SYS-GMM). The inclusion of lagged difference variables as instrumental variables in SYS-GMM enhances the reliability of estimation results compared to the DIF-GMM (Blundell *et al.*, 2001). Therefore, we use the SYS-GMM as the method of analysis. The results are reported in Table 5. The outcomes of the robustness tests are consistent with those of results obtained from the baseline model regressions, thus suggesting that the results of this analysis are reliable.

$$ISU_{i,t} = Y_{1it} \times 1 + Y_{2it} \times 2 + Y_{3it} \times 3 \quad (7)$$

where Y_{1it}, Y_{2it} and Y_{3it} refer to the primary, secondary, and tertiary industries as a share of GDP, respectively.

Table 5: Results of the Sensitivity Test

	(1)	(2)	(3)
	Substituting Variable	**Adding Variable**	**SYS-GMM**
ISU	1.2738** (0.5894)	0.3580** (0.1478)	0.5951** (0.2641)
OPEN	−0.0388 (0.0766)	−0.0143 (0.0681)	0.0698** (0.0309)
HC	−0.6965 (0.7561)	−0.3725 (0.6756)	−0.0895 (0.3073)
FIN	−0.0464 (0.1941)	−0.1295 (0.1766)	0.0163 (0.0661)
PERGDP	0.3889*** (0.1203)	0.5596*** (0.1115)	0.0091 (0.0447)
MAR	0.1603 (0.2328)	0.1426 (0.2326)	0.1620 (0.1209)
INF		−0.3858*** (0.1258)	
L.GTFP			0.8000*** (0.0687)
Constant	−5.5865*** (1.5592)	−5.1690*** (1.1327)	−1.3936** (0.5811)
***F*-statistic**	29.9659***	34.6474***	189.8486***
Observations	570	570	540
AR(1)			0.0240**
AR(2)			0.3390
Hansen			0.1360

Notes: AR (1) being statistically significant suggests first-order autocorrelation, while AR (2) being statistically not significant indicates the absence of second-order autocorrelation, confirming the validity of the instrumental variable. Hansen test is statistically not significant, indicating that the instrumental variables are valid.
Source: Authors' own calculations

4.3 Threshold effect

To identify the appropriate threshold effect model, we first assess the existence of the threshold effect (see Hansen, 2000). Outcomes in

Table 6 indicate a statistically significant single threshold with F = 25.360 and p = 0.006, but a statistically insignificant double threshold with F = 6.280 and p = 0.554. Therefore, we establish a threshold effect model based on Equation (5), shown by Equation (8). We determine the threshold value for environmental regulation (ER) through the minimization of the residual sum of squares, as presented in Source: Authors' own calculations

$$GTFP_{i,t} = \beta_0 + \beta_1 ISU_{i,t}(ER_{it} \leq \gamma_1) + \beta_2 ISU_{i,t}(ER_{it} > \gamma_1) + \theta X_{it} + \varepsilon_{it} \tag{8}$$

Table 6: Threshold Effect Test

Threshold Variable	Threshold Type	*F*-statistics	*p*-value	Bootstrap	Critical Value		
					1%	5%	10%
ER	**Single**	25.360	0.006	500	24.975	17.649	14.310
	double	6.280	0.554	500	21.595	16.381	13.468

Source: Authors' own calculations

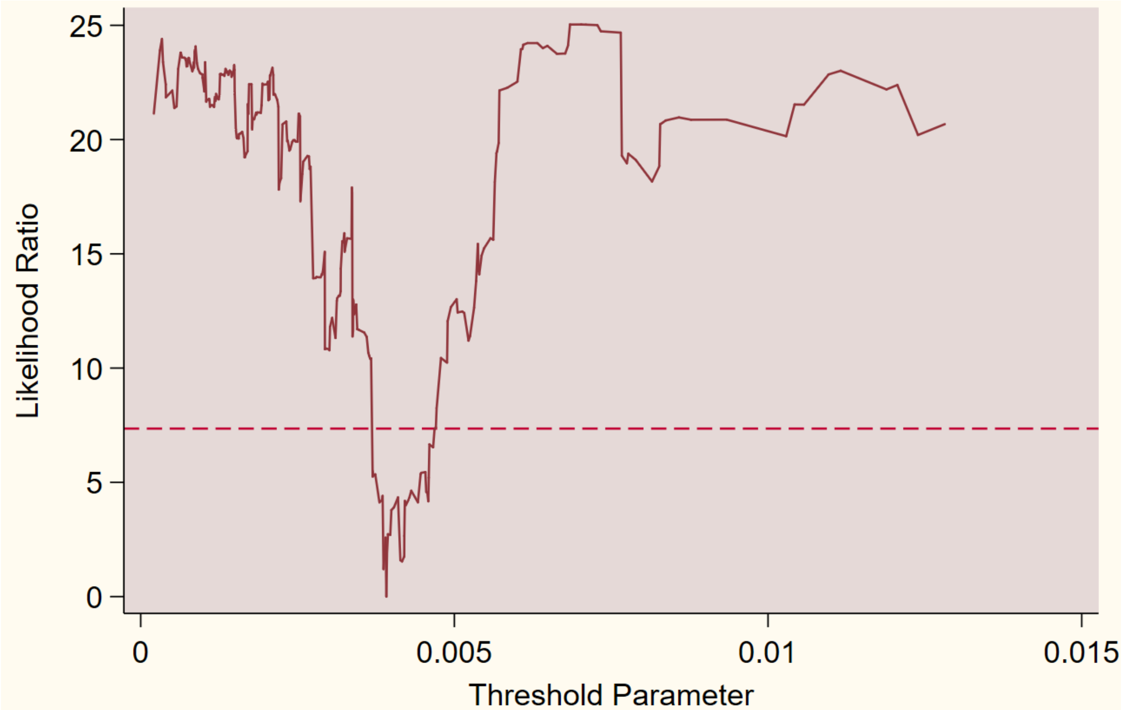
Table 7: Threshold Estimator and Confidence Interval

Threshold Type	Threshold Value	95% Confidence Interval
Single	0.0039	(0.0038, 0.0039)

Source: Authors' own calculations

Second, as depicted in Figure 4, we plot the Likelihood Ratio (LR) function graph, employing the information in Table 7 to assess the consistency of the threshold estimates. The LR statistic for the threshold value falls below the critical value of 7.35, which confirms the validity of the threshold estimates.

Figure 4: Likelihood Ratio Function Diagram



Note: Horizontal axis – threshold estimator, Vertical axis – likelihood ratio statistic LR. The red dotted line represents the critical value of LR at the 5% level (7.35).

Source: Authors' own elaboration

Based on the threshold value of 0.0039, the full sample is divided into two regimes: low-standard environmental regulation ($ER \leq 0.0039$). and high-standard environmental regulation ($ER > 0.0039$). The results are summarized in Table 8. When environmental regulation is at or below 0.0039, the coefficient of *ISU* is estimated at 0.474 (p = 0.000). However, when environmental regulation exceeds 0.0039, the coefficient decreases significantly to 0.227 (p = 0.001). This indicates that when environmental regulatory standards exceed the threshold, the positive effect of *ISU* weakens. Thus, hypothesis H_2 is corroborated.

Table 8: The Result of Threshold Effect Estimation

	Coefficient	Standard Error	*t*-statistic	*p*-value
ISU **(*ER* ≤ 0.0039)**	0.474***	0.057	8.320	0.000
ISU **(*ER* > 0.0039)**	0.227**	0.069	3.290	0.001
OPEN	−0.006	0.029	−0.190	0.846
HC	−0.701***	0.232	−3.030	0.003
FIN	−0.108	0.065	−1.640	0.101
PERGDP	0.444***	0.037	12.100	0.000
MAR	0.109	0.100	1.090	0.275
Constant	−3.015***	0.374	−8.060	0.000
R^2	0.716			
F-statistic	192.070***			
Observations	570			

Source: Authors' own calculations

4.4 Moderation effect

To test hypothesis H_3, we rewrite Equation (6) to obtain Equation (9).

$$GTFP_{i,t} = \alpha_0 + (\alpha_1 + \alpha_3 PRESSURE_{i,t}) \times ISU_{i,t} + \alpha_2 PRESSURE_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \qquad (9)$$

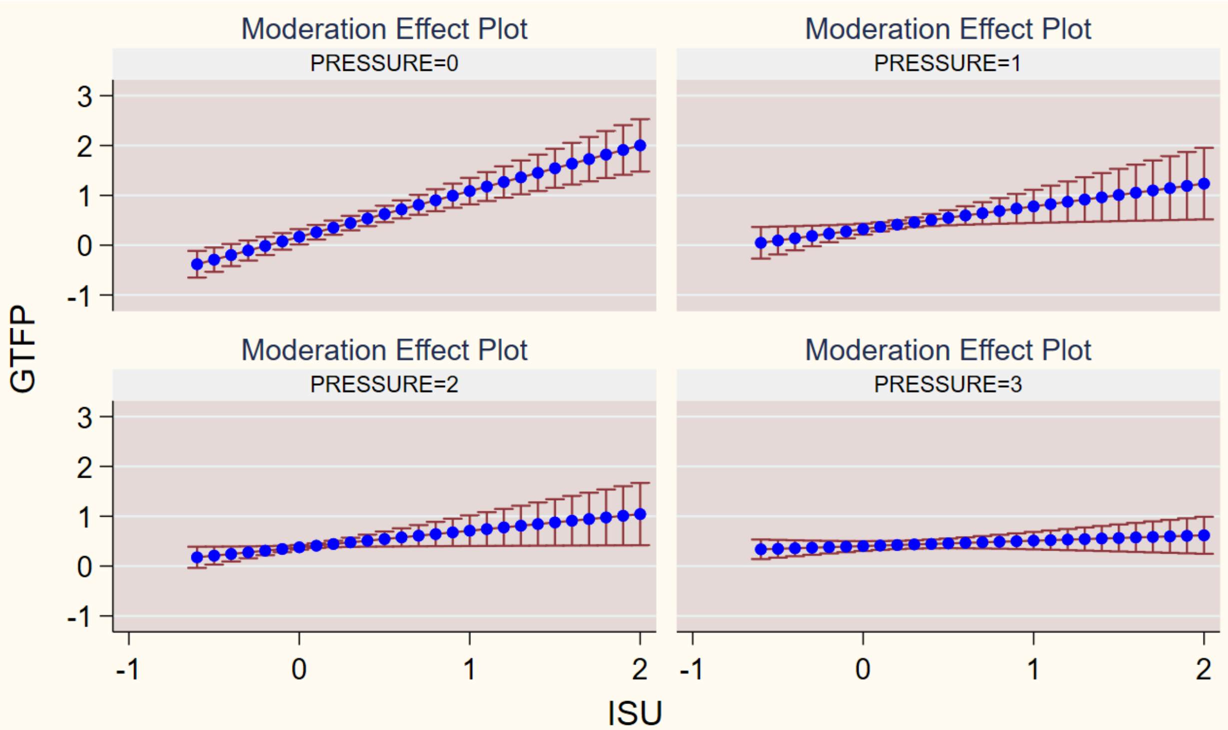
Table 9: Estimated Result of Moderation Effect

	Coefficient	Standard Error	*t*-statistic	*p*-value
ISU	0.835***	0.186	4.490	0.000
PRESSURE	0.022	0.042	0.530	0.602
ISU* × *PRESSURE	−0.248***	0.057	−4.350	0.000
OPEN	−0.002	0.062	−0.020	0.981
HC	−0.445	0.608	−0.730	0.471
FIN	0.001	0.134	0.010	0.996
PERGDP	0.387***	0.090	4.310	0.000
MAR	0.142	0.207	0.690	0.498
Constant	−3.175***	0.810	−3.920	0.001
Observations	570			
R^2	0.741			
F-statistic	38.860***			

Source: Authors' own calculations

Table 9 presents the regression results of Equation (6). The coefficient of *ISU* (α_1 = 0.835. p = 0.008) is statistically significant and positive at the 1% level. The coefficient of the interaction term α_3 is −0.248 with p = 0.000, indicating that *PRESSURE* significantly moderates the relationship between *ISU* and *GTFP*. With the inclusion of the interaction term, the marginal effect of *ISU* on *GTFP* is 0.835 – 0.248 × *PRESSURE*. Based on the estimation results, we plot a graph of the moderation effect (see Figure 5). The graph demonstrates that the marginal effect of *GTFP* decreases as *PRESSURE* increases. Thus, the findings suggest that *PRESSURE* negatively moderates the relationship between *ISU* and *GTFP*. In other words, under promotion pressure, local officials may prioritize their political accomplishments over the achievement of the quality of economic development in their respective regions. This focus on promotion incentives often leads to the neglect of industrial optimization and environmental protection in policy-making, ultimately hindering *GTFP*. These findings therefore support hypothesis H_3.

Figure 5: Moderation effect plot



Source: Authors' own elaboration

4.5 Discussion

The present study employs the global Malmquist–Luenberger index to assess *GTFP* across 30 Chinese provinces from 2005 to 2023, offering a nuanced understanding of how industrial structure upgrading and local officials' promotion pressure shape sustainable economic efficiency. This methodological choice comprehensively accounts for environmental constraints in productivity measurement, aligning with the growing emphasis on integrating ecological costs into economic assessments (Senthil *et al*., 2003). By situating the analysis within China's unique political-economic context, the study captures the interplay between market-driven structural transformation and institutionally embedded incentives, thereby enhancing the relevance of its findings for both academic discourse and policy design.

First, the identification of a significant positive effect of industrial structure upgrading on *GTFP* underscores the critical role of sectoral reallocation in fostering sustainable growth. This finding resonates with the "structural bonus" hypothesis, whereby resources shift from low-efficiency to high-efficiency sectors (Wang *et al.* 2024). In China's case, such upgrading not only boosts technological innovation through knowledge spillovers but also promotes resource optimization, reducing energy intensity and pollution emissions. For example, the rise of digital manufacturing and renewable energy sectors has simultaneously enhanced economic output and environmental performance, illustrating how industrial transformation can achieve "win-win" outcomes for growth and sustainability.

Second, the study's revelation of a threshold effect in environmental regulation adds complexity to the policy-efficiency relationship. While moderate regulation incentivizes firms to adopt cleaner technologies through the "innovation compensation effect" (Phung *et al*., 2023), excessively strict standards may impose prohibitive compliance costs, diverting resources from productive innovation and hindering technological transformation. This trade-off highlights the importance of calibrating regulatory intensity to local economic and environmental capacities. For instance, in resource-dependent regions where industrial upgrading faces structural challenges, overly abrupt regulatory tightening could exacerbate short-term efficiency losses, whereas gradual, market-based instruments (e.g., carbon pricing or emission trading) might facilitate smoother transitions by aligning private costs with social benefits.

Third, the finding that political incentives adversely moderate the positive correlation between industrial upgrading and *GTFP* is a critical contribution to understanding institutional influences on green productivity. Rooted in China's "promotion tournament" system (Zhou, 2007), this result demonstrates how the evaluation mechanism with GDP-centric can incentivize local leaders to prioritize short-term economic gains through resource-intensive industries, even at the expense of environmental sustainability. Such behavior may manifest in relaxed regulatory enforcement to attract polluting enterprises or overinvestment in heavy manufacturing, both of which undermine the long-term efficiency of industrial structure. This mechanism echoes broader debates on political economy and sustainable development, highlighting how governance structures shape the balance between growth imperatives and ecological objectives.

Finally, the study's focus on China's context provides a unique lens for examining how institutional arrangements moderate the effects of economic policies. While industrial upgrading is a universal pathway to productivity growth, the role of political incentives in mediating its environmental outcomes is particularly salient in systems where local officials wield significant economic authority. The findings suggest that aligning governance mechanisms, such as incorporating green metrics into performance evaluations or enhancing environmental regulatory independence, could mitigate the negative spillover of promotion pressure, fostering a more sustainable trajectory for structural transformation.

In synthesizing these insights, the study advances our understanding of how multi-dimensional factors, such as economic structure, policy design, and political institutions, interact to influence green productivity. By highlighting the conditional effects of environmental regulation and the role of governance incentives, the research underscores the need for integrated policy solutions that balance market efficiency with institutional realities.

5. Conclusion Remarks

5.1 Conclusion

The current study evaluates the *GTFP* of 30 provincial units in China for the years 2005 to 2023. In addition, it investigates the correlations between key variables, leading to three main conclusions. First, industrial structure upgrading in China significantly improves *GTFP*. Second, when environmental regulatory standards surpass a certain threshold, the positive impact of industrial constitution optimization on *GTFP* diminishes. While moderate environmental regulation can incentivize companies to enhance manufacturing processes and pollution control measures by improving the compensation effect of innovation, overly strict environmental regulations may result in increased pollution control costs, thereby crowding out investments in innovation, and hindering technological transformation and efficiency improvements within companies. Finally, a third finding suggests that the relationship between industrial system improvement and *GTFP* is inversely related to the promotion pressure of local officials. Under the unique political system in China, the main criteria for assessing the promotion of local officials are centered around economic performance, thus encouraging the development of secondary industries that provide a quick impact on the economic growth of their regions. However, these industries often result in extensive consumption of natural resources and generate environmental damage. In addition, local governments may relax environmental regulations to attract industrial enterprises and increase industrial production. Therefore, while the upgrading of the industrial system has led to improvements in *GTFP* its influence diminishes as a consequence of the existence of promotion pressure among local bureaucrats.

5.2 Policy implications

This work also offers critical policy implications to enhance *GTFP* amid industrial structure upgrading and unique political incentives in China. First, policymakers should prioritize strategies that accelerate structural transformation toward green sectors by fostering high-tech industries, improving factor mobility, and reducing market distortions to amplify efficiency gains from upgrading. Second, environmental regulation must be calibrated to avoid excessive strictness that crowds out innovation, adopting dynamic and regionally differentiated standards, such as market-based instruments in moderate-growth regions and transitional support for resource-dependent cities, to balance innovation incentives with environmental goals. Finally, to address the negative impact of officials' promotion pressure, integrating green metrics (*e.g.*, *GTFP* growth, carbon intensity) into political accountability systems, strengthening independent environmental enforcement, and promoting multi-term assessments can align officials' incentives with sustainable development, discouraging short-term, high-pollution growth strategies.

5.3 Research limitations and future research directions

The present study investigates the effects of industrial structure upgrading and local officials' promotion pressure on *GTFP* in China, yet it has several limitations that warrant attention. First, although the analysis utilizes provincial-level panel data spanning 2005 to 2023, data availability and consistency across regions may vary, particularly regarding environmental pollution emissions and officials' career trajectories, which could introduce minor biases into the empirical results. Second, the focus on China's unique political-economic context, while providing in-depth insights into the interplay between institutional incentives and green productivity, may limit the generalizability of conclusions to other countries with different governance structures, even among emerging economies with similar development stages. Third, the study primarily operates at the macro and meso levels, potentially overlooking micro-level mechanisms, such as how firms with varying ownership types (*e.g.*, state-owned and private enterprises) respond differently to industrial policies under promotion pressure, thus leaving the black box of firm-level heterogeneity partially unaddressed.

These limitations offer fertile ground for future research. Specifically, expanding the analytical framework to include comparative studies of other emerging economies with analogous political-economic systems (*e.g.*, Vietnam, India) could enhance the external validity of the conclusions and shed light on universal or context-specific challenges in aligning industrial upgrading with green productivity. Second, incorporating firm-level data to explore heterogeneous responses to promotion pressure and environmental regulation would deepen the understanding of micro-level transmission channels. Finally, integrating qualitative methods, such as case studies of typical resource-based cities or high-tech industrial clusters, could provide nuanced insights into the complex interactions between policy implementation, local governance, and sustainable development outcomes. By addressing these avenues, future studies can contribute to a more comprehensive understanding of how governance structures shape green economic transformation in an era of global environmental challenges.

Highlights

- Industrial structure upgrading significantly improves green total factor productivity.
- The impact of industrial constitution optimization on green total factor productivity is non-linear.
- Promotion pressure on local officials weakens the positive effect of industrial upgrading on green total factor productivity.

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Declaration of Interest Statement

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

Data availability

Datasets used or analyzed during this study are available from the first author on reasonable request.

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Authors' Contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Le Xiaobing. The first draft of the manuscript was written by Le Xiaobing and Dr. Sarma Binti Aralas commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

Albulescu, C. T., Ajmi, A. N., Miclea, S., Cernescu, L. M. (2025). Total factor productivity and firm size in the German energy industry: Evidence from a symbolic transfer entropy panel causality test. Journal of Applied Economics, 28(1). https://doi.org/10.1080/15140326.2025.2453253

Ameer, W., Sohag, K., Zhan, Q., Shah, S. H., Yongjia, Z. (2025). Do financial development and institutional quality impede or stimulate the shadow economy? A comparative analysis of developed and developing countries. Humanities and Social Sciences Communications, 12, 17. https://doi.org/10.1057/s41599-024-04347-w

Bai, J., Nie, L. (2018). Energy efficiency, environmental pollution, and the transformation of China’s economic development model. *Financial Research* (10), 1-18.

Blundell, R., Bond, S., Windmeijer, F. (2001). Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator. *Nonstationary panels, panel cointegration, and dynamic panels*, 53-91. https://doi.org/10.1016/S0731-9053(00)15003-0

Bosworth, B., Collins, S. M. (2008). Accounting for growth: comparing China and India. *Journal of Economic Perspectives*, 22(1), 45-66. https://doi.org/10.1257/jep.22.1.45

Cai, W, Zhou, X. (2017). The dual effects of China’s environmental regulations on green total factor productivity. *The Economist* (09), 27-35. https://doi.10.16158/j.cnki.51-1312/f. 2017.09.005

Chen, B., Wang, W. (2021). Internet, industrial structure upgrade, and green total factor productivity. *Ecological Economics* (12), 43-53.

Chen, G. (2009). FDI competition, environmental regulation, and pollution refuges - reflections on Chinese-style decentralization. *World Economic Research*, (6), 3-7, 43-87.

Chen, S. (2010). China's green industrial revolution: An interpretation from the perspective of environmental total factor productivity (1980-2008). *Journal of Economic Research,* 45(11), 21-34.

Chung, Y. H., Färe, R., Grosskopf, S. (1997). Productivity and undesirable outputs: a directional distance function approach. *Journal of Environmental Management,* 51(3), 229-240. https://doi.org/10.1006/jema.1997.0146

Cole, D. W., Cole, R., Gaydos, S. J., et al. (2009). Aquaculture: Environmental, toxicological, and health issues. *International Journal of Hygiene and Environmental Health*, *212*(4), 369-377. https://doi.org/10.1016/j.ijheh.2008.08.003

Dong, Y., Xie, B. (2022). The impact of environmental regulations on green total factor productivity in China's thermal power industry - an empirical study based on provincial panel data. *Ecological Economics*, (02), 51-58.

Dvouletý, O., Blažková, I. (2021). Exploring firm-level and sectoral variation in total factor productivity (TFP). International Journal of Entrepreneurial Behavior & Research, 27(6), 1526–1547. https://doi.org/10.1108/IJEBR-11-2020-0744

Elsadig, M., Ahmed (2012). Green TFP intensity impact on sustainable East Asian productivity growth. *Economic Analysis and Policy*, 42(1), 67–78. https://doi.org/10.1016/S0313-5926(12)50005-6

Feng, J., Zhang, S.(2017). Inter-provincial green total factor productivity assessment based on DEA method: An analysis of differences among different model choices. *Journal of Peking University (Natural Science Edition)*, (1), 151-159. https://doi.10.13209/j.0479-8023.2016.119.

Feng, Z., Chen, W., Yang, C. (2017). Differences in environmental regulations, innovation drive, and China's green economic growth. *Technical Economics*, (08), 61-69.

Fukuyama, H., Weber, W. L. (2009). A directional slacks-based measure of technical inefficiency. *Socio-Economic Planning Sciences*, 43(4), 274–287. https://doi.org/10.1016/j.seps.2008.12.001

Gan, C. H., Zheng, R. G., & Yu, D. F. (2011). The impact of China's industrial structure change on economic growth and fluctuations. *Economic Research*, 46(5), 4–16, 31.

Ge, J., Liu, R. M. (2022). China's economic growth, fluctuations, and regional disparities: An explanation based on economic transformation. Academic Monthly, 54(2), 63–78. https://doi.org/10.19862/j.cnki.xsyk.000362

Han, J., Chen, X. (2022). Digital economy enabling green development: Internal mechanisms and empirical evidence. *Comparison of Economic and Social Systems*, (2), 73–84. https://doi.org/10.3969/j.issn.1003-3947.2022.02.008

Han, J., Sun, Y., Chen, C., Lan, Q. (2019). Does industrial upgrading promote green urban growth in China? *Journal of Beijing Normal University (Social Science Edition)*, (03),139-151.

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics*, 93(2), 345-368. https://doi.org/10.1016/S0304-4076(99)00025-1

Hansen, B. E. (2000). Sample splitting and threshold estimation. *Econometrica*, 68(3), 575-603. https://doi.org/10.1111/1468-0262.00124

He, X. Y., Shen, K. R. (2018). Modern economic system, total factor productivity, and high-quality development. *Shanghai Economic Review*, (6), 25–34.

Hosan, S., Karmaker, S. C., Rahman, M. M., Chapman, A. J., Saha, B. B. (2022). Dynamic links among the demographic dividend, digitalization, energy intensity, and sustainable economic growth: Empirical evidence from emerging economies. Journal of Cleaner Production, 330, 129858. https://doi.org/10.1016/j.jclepro.2021.129858

Ke, L. F., Yu, D. J. (2024). Study on the mechanism of green economic growth promoting industrial structure upgrading: An empirical analysis based on provinces in western China. *Economic and Social Development*, 22(2), 1–13. https://doi.10.3969/j.issn.1672-2728.2024.02.002

Ke, S., Zhao, Y. (2014). Industrial structure, city size, and urban productivity in China. *Economic Research*, (04), 76-88.

Krugman, P. (1994). The myth of Asia's miracle. *Foreign Affairs*, 73(6), 62–78. https://doi.org/10.2307/20046929

Li, H., Zhou, L. A. (2005). Political turnover and economic performance: the incentive role of personnel control in China. *Journal of Public Economics*, 89(9-10), 1743-1762. https://doi.org/10.1016/j.jpubeco.2004.06.009

Li, M. (2009). Causes and countermeasures of frequent environmental damage incidents in China – based on the perspective of inter-regional environmental competition. *Finance and Trade Economics*, (09), 82-88. https://doi.10.19795/j.cnki.cn11-1166/f.2009.09.011

Liao, H., Gong, P. (2020). Factor flow and China's industrial structure optimization under the background of One Belt and One Road. *Journal of Jinan University (Social Science Edition)*, (05), 99-109.

Liu, K., Luo, J., Faridi, M. Z., Nazar, R., Ali, S. (2025). Green shoots in uncertain times: Decoding the asymmetric nexus between monetary policy uncertainty and renewable energy. Energy & Environment. https://doi.org/10.1177/0958305X241310198

Liu, R., He, C. (2021). Threshold effect of environmental regulation on urban income inequality. *Chinese Soft Science*, (08), 41-52.

Liu, Y., Yang, Y., Li, H., Zhong, K. (2022). Digital economy development, industrial structure upgrading and green total factor productivity: Empirical evidence from China's cities. *International Journal of Environmental Research and Public Health*, 19(4), 2414. https://doi.org/10.3390/ijerph19042414

Lu, Z. G., Zhao, P. Y. (2020). A study on the dynamic relationship and regional differences among financial efficiency, industrial structure upgrading, and total factor productivity: Evidence from Guangdong Province. *Exploration of Economic Issues*, (10), 94–109.

Lyu, Y., Wang, W., Wu, Y., Zhang, J. (2023). How does the digital economy affect green total factor productivity? Evidence from China. Science of the Total Environment, 857, 159428. https://doi.org/10.1016/j.scitotenv.2022.159428

Maskin, E., Qian, Y., Xu, C. (2000). Incentives, information, and organizational form. *The Review of Economic Studies*, *67*(2), 359-378. https://doi.10.2139/ssrn.60829

Pai, M. K. (2016). The technical progress and resilience in productivity growth of Korea's growth-leading industries. *Asian Economic Papers*, *15*(2), 167-191. https://doi.org/10.1162/ASEP_a_00441

Phung, G., Trinh, H. H., Nguyen, T. H., Trinh, V. Q. (2023). Top-management compensation and environmental innovation strategy. *Business Strategy and the Environment*, *32*(4), 1634-1649. https://doi.org/10.1002/bse.3209

Qian, X., Cao, T., Li, W. (2011). Promotion pressure, official tenure, and the lending behavior of urban commercial banks. *Economic Research*, (12), 72-85.

Qiao, K. Y. (2013). Re-examining the promotion tournament mechanism for Chinese officials: Evidence from provincial and municipal governments. *Journal of Finance and Economics*, 39(4), 123–133. https://doi.10.16538/j.cnki.jfe.2013.04.001

Ramanathan, R. (2005). An analysis of energy consumption and carbon dioxide emissions in countries of the Middle East and North Africa. *Energy*, 30(15), 2831-2842. https://doi.10.1016/j.energy.2005.01.010

Sang, Y. Yan, B. (2014). Optimization of the hierarchical structure of the national governance system. *Journal of Shandong University (Philosophy and Social Sciences Edition)*, (06), 1-8.

Senthil, K. D., Ong, S. K., Nee, A. Y. C., Tan, R. B. (2003). A proposed tool to integrate environmental and economical assessments of products. *Environmental Impact Assessment Review*, *23*(1), 51-72. https://doi.org/10.1016/S0195-9255(02)00032-X

Sharma, H., Padhi, B. (2024). Transiting towards green productivity: Evidence from Indian organized manufacturing industries. Journal of Environmental Management, 373, 123662. https://doi.org/10.1016/j.jenvman.2024.123662

Song, D. Y., Zhang, Q. (2022). Evolution and driving force of the integration of environmental protection and high-quality economic development. Research on Quantitative and Technical Economics, 39(8), 42–59. https://doi.org/10.13653/j.cnki.jqte.2022.08.008

Sun, J., Tang, D., Kong, H., Boamah, V. (2022). Impact of industrial structure upgrading on green total factor productivity in the Yangtze River economic belt. *International Journal of Environmental Research and Public Health*, *19*(6), 3718. https://doi.org/10.3390/ijerph19063718

Sun, Y., Sun, S. (2014). The impact of industrial structure optimization and upgrading on economic growth. *Modern Economic Information*, (09), 420-421.

Tian, G., Hu, F. (2023). Horizontal tax competition, official turnover, and urban green total factor productivity: Panel evidence from 41 cities in the Yangtze River Delta. *East China Economic Management*.

Timmer, M. P., Szirmai, A. (2000). Productivity growth in Asian manufacturing: the structural bonus hypothesis examined. *Structural Change and Economic Dynamics,* 11(4), 371-392. https://doi.10.1016/S0954-349X(00)00023-0

Tone, K., Sahoo, B. K. (2003). Scale, indivisibilities, and production function in data envelopment analysis. *International Journal of Production Economics*, 84(2), 165-192. https://doi.10.1016/S0925-5273(02)00412-7

Tong, L., Jabbour, C. J. C., Belgacem, S. B., Najam, H., Abbas, J. (2022). Role of environmental regulations, green finance, and investment in green technologies in green total factor productivity: Empirical evidence from the Asian region. Journal of Cleaner Production, 380, 134930. https://doi.org/10.1016/j.jclepro.2022.134930

Tu, Z. G., Chen, L. (2019). The direction of technological progress and high-quality economic development: From the perspectives of total factor productivity and industrial structure upgrading. *Journal of China University of Geosciences (Social Sciences Edition)*, 19(3), 119–135. https://doi.10.16493/j.cnki.42-1627/c.2019.03.012

Wang, J., Xu, H., Wang, M. (2025). Technology diffusion considers technological progress and multiple policy combinations based on evolutionary game theory. Technology in Society, 81, 102799. https://doi.org/10.1016/j.techsoc.2024.102799

Wang, K., Zhao, B., Ding, L. (2021). Economic catch-up, structural transformation, and green total factor productivity. *Journal of Shanxi University of Finance and Economics*, (01), 15-26. https://doi.10.13781/j.cnki.1007-9556.2021.01.002

Wang, S., Zhou, M., Zhong, S. (2020). Research on the impact of manufacturing agglomeration in resource-based areas on industrial structure upgrading: taking Shanxi Province as an example. *Exploration of Economic Issues*, (02), 85-93.

Wang, X., Lu, Y., Chen, C., Yi, X., Cui, H. (2024). Total-factor energy efficiency of ten major global energy-consuming countries. *Journal of Environmental Sciences*, *137*, 41-52. https://doi.org/10.1016/j.jes.2023.02.031

Wang, X., Xu, X. (2010). Promotion competition of local officials and economic growth. *Economic Science*, (06), 42-58. https://doi.10.19523/j.jjkx.2010.06.003

Wu, J., Deng, Y., Huang, J., Morck, R., Yeung, B. (2013). Incentives and outcomes: China's environmental policy. *Social Science Electronic Publishing*, 9(1), 1-41. https://doi.10.2139/ssrn.2206043

Xia, F., Xu, J. T. (2020). Green total factor productivity: A re-examination of quality of growth for provinces in China. *China Economic Review*, 62. https://doi.org/10.1016/j.chieco.2020.101454

Xie, R., Fu, W., Yao, S., Zhang, Q. (2021). Effects of financial agglomeration on green total factor productivity in Chinese cities: insights from an empirical spatial Durbin model. *Energy Econ*, 101, 105449. https://doi.org/10.1016/j.eneco.2021.105449

Xie, S., Bashir, M. F. (2024). Institutional differences, state ownership, and financing decisions: Evidence from Chinese cross-border mergers and acquisitions. International Finance, 27, 309–338. https://doi.org/10.1111/infi.12455

Xu, J., Liu, Z., Ping, J., Zhang, R. (2022). Do dual environmental regulations improve green total factor productivity? Analysis of threshold effect based on industrial structure upgrading. *Research World*, (09), 80-88. https://doi.10.13778/j.cnki.11-3705/c.2022.09.009

Xu, X. X., Li, X., Wang, M. J. (2007). Regional integration, economic growth, and political promotion. *China Economic Quarterly*, (4), 1075–1096.

Xu, X., Wang, X. (2010). Promotion incentives and economic growth: Evidence from provincial officials in China. *World Economy*, (02), 15-36. https://doi.10.19985/j.cnki.cassjwe.2010.02.002

Xu, Y., Yin, C. (2021). Calculation of China’s agricultural green total factor productivity under environmental regulations. *Statistics and Decision Making* (18), 50-54. https://doi.10.13546/j.cnki.tjyjc.2021.18.011

Yang, H. M., Jiang, L. (2021). Digital economy, spatial effects, and total factor productivity. *Statistical Research*, 38(4), 3–15. https://doi.10.19343/j.cnki.11-1302/c.2021.04.001

Yang, Z., Wang, J.(2018). Fiscal decentralization and green Total factor Productivity: Based on system GMM and threshold effect test. *Ecological Economy*, (11), 132-139.

Yin, H., Zhang, L., Ye, X. S. (2020). The time-varying effect of China’s industrial structure adjustment on total factor productivity. *The Journal of World Economy*, 43(1), 122–142. https://doi.10.19985/j.cnki.cassjwe.2020.01.008

You, D. M., Zhang, Y., Yuan, B. L. (2019). The impact of environmental regulation on industrial structure upgrading under fiscal decentralization and promotion incentives. Journal of Jishou University: Social Sciences Edition. https://doi.org/10.13438/j.cnki.jdxb.2019.02.003

Yu, B. (2017). How does industrial structure adjustment improve regional energy efficiency? An empirical investigation based on the dual dimensions of magnitude and quality. *Financial Research*, (01), 86-97. https://doi.10.16538/j.cnki. jfe.2017.01.008

Yuan, B., Xiang, Q. (2018). Environmental regulation, industrial innovation and green development of Chinese manufacturing: Based on an extended CDM model. *Journal of Cleaner Production*, *176*, 895-908.

Zhang, P., Zhang, J. X., Cui, F. (2017). Environmental pollution, energy consumption, and official promotion during industrialization. *Journal of Public Administration Review*, 10(5), 46–68, 216.

Zhang, Q. J., Lü, X. R., Chen, J. H., Tao, X. F. (2024). The spatiotemporal characteristics of urban shrinkage in the Yangtze River Delta and the internal mechanism of the impact of digital economy. *Economic Geography*, 44(10), 76–85. https://doi.10.15957/j.cnki.jjdl.2024.10.008

Zhang, Y. (2020). Government cooperation and total factor productivity in urban agglomerations: A quasi-natural experiment based on the Yangtze River Delta Urban Economic Coordination Conference. *Fiscal Studies*, (4), 83–98. https://doi.10.19477/j.cnki.11-1077/f.2020.04.009

Zhong, W., Wang, J. (2010). Research on local government behavioral incentives and regional energy efficiency in my country. *Management World* (06), 171-172. https://doi.10.19744/j.cnki.11-1235/f.2010.06.019

Zhou, L. A. (2004). Incentives and cooperation among government officials in promotion tournaments: A discussion on the long-term existence of local protectionism and duplicate construction in China. *Economic Research*, (6), 33–40.

Zhou, L. A. (2007). A study on the promotion tournament model for Chinese local officials. *Economic Research*, 42(7), 15.

Zhou, L. A., Tao, J. (2011). Promotion competition among officials and border effects: Evidence from economic development in provincial border areas. *Journal of Financial Research*, (3), 15–26.

Zhou, R, Liu, Y., Yang, X. (2021). Environmental regulation intensity and aggregate total factor productivity of enterprises in the industry. *Journal of Nanjing University of Finance and Economics* (05), 86-96.

Zhu, X., Zhang, B., Yuan, H. (2022). Digital economy, industrial structure upgrading and green total factor productivity: Evidence in textile and apparel industry from China. *PlosOne*, 17(11).