Digital Economy, Environmental Regulation and Green Industrial Shift: Cities in the Yangtze River Basin

Yuhang Xu

2022110305@ecut.edu.cn

School of Economics and Management, East China University of Technology, Nanchang, China

Abstract. In a context of dual resource and environmental constraints, a pivotal facet of achieving resilient economic expansion involves globally enhancing ecological resource utilization. As the tech-driven economy plays an increasingly prominent role in optimizing resource allocation, there is a pressing need to delve deeper into the procedure governing the overall productivity of ecological factors. This study undertakes a comprehensive exploration through theoretical discourse and empirical testing to understand the impact of the digital economy on conservation legislation and the collective sustainability output. Utilizing sample data from 108 cities along the Yangtze River during the period 2014-2021, we employ the top-tier SBM effectiveness model to gauge collective green resource effectiveness. Furthermore, the investigation employs DID and DDD methods to scrutinize the effects of environmental policies and the digital economic landscape on the industry's overall eco-conscious output. The findings indicate that the implementation of environmental policies contributes to the enhancement of overall eco-efficiency of production. As novel productivity evolves, the beneficial moderating role played by digital innovation for both factors. This underscores the growing influence of the cyber economy alongside the continued growth of innovative productivity.

Keywords: Sustainable policy; Digitalization of the economy; Holistic factor performance in environmentally friendly industries; Yangtze River Zone.

1 Introduction

As China undergoes a shift in its economic development trajectory, transitioning from a phase of vigorous Expansion to one characterized by a focus on optimal Progress, the dynamics of its economic landscape are evolving, and the demand for simultaneous progress in overall development and environmental protection is on the rise. The Yangtze River cities, because of its unique ecological status and huge development potential, occupy a pivotal position in the Chinese economy. According to statistics, from 2018 to 2022, there were 1067 environmental emergencies in China, of which 39.64% occurred Yangtze River corridor. Notably during 2022, the segment of disasters within the ecosystem in this region increased to 48.67%. For the time being, the influence of sustainable policy on industrial green transformation is slightly improved but not obvious enough, and there are problems such as occupying enterprise innovation investment, but its long-term effect is worthy of further research and verification.

Per this, we focus on sampled information from 108 cities in the Yangtze River area, covering

ICBBEM 2024, March 29-31, Wuhan, People's Republic of China

DOI 10.4108/eai.29-3-2024.2347407

the time frame of 2014 through 2021. The primary objective is to assess the industrial complete nature's productive capacity using the top-tier SBM effectiveness model. Analyzing the impact of ecological oversight on the efficiency of green manufacturing yield in the Yangtze River strip is undertaken through DID methodology, considering policy variations.

2 Research Framework

Researchers have investigated the impact of three distinct factors: facilitation, deterrence and uncertainty[1].The introduction of ecological oversight increases the credibility of environmental policies and increases contamination expenditure (e.g., direct and opportunity expenses) for firms. From a long-term perspective, the cost of a certain intensity of environmental regulation will motivate industrial enterprises to further optimize internal resource allocation and organizational management, so that the compensation obtained in the transformation and upgrading will gradually reduce or even offset the original undesirable ramifications [2-5].

Overall, in the immediate timeframe, the cost implications of ecological oversight on industrial integrated ecological efficiency compliance are anticipated to result in increased financial burdens for industrial entities, thereby exerting an inhibitory effect on overall productivity. However, over the long run, it is posited that judicious ecological oversight will contribute to enhancing the operational efficiency of industrial entities, ultimately fostering the improvement of industrial integrated ecological efficiency (see Figure 1). Building upon this premise, our set of hypotheses:

Hypothesis 1: The affirmative influence of ecological oversight on the enhancement of industrial complete green factor output is anticipated.

Academics have probed into the two influences of the Internet commerce domain on ecological supervision and the overall efficiency of green resources[6]. There are differences in infrastructure and digital technology in different regions[7]. As a new economic form, the e-commerce sector has a variety of characteristics that are conducive to the efficiency of green production factors, such as positive externalities and long-tail effects. Amidst the backdrop of increasingly stringent ecological oversight, companies find themselves under substantial constraints regarding operational budget, and the e-commerce sector, with the penetration and low-cost advantages of cybernetic solutions, can grant credit aid to enterprises and regions with capital needs, broaden their financing channels, ensure cohesive development of innovation ventures[8-10]. Moreover, with the help of cybernetic solutions, the government realizes the streamlining of administration and the optimization of functions, which is conducive to building a service-oriented government, providing a favorable market environment and solid institutional backing for the implementation of ecological oversights.

In conclusion, the e-commerce sector holds the capacity to provide enterprises with not only newfound financial support but also a novel avenue for the government to supervise pollution-related activities effectively, driving the dual cycle of environmental regulation and economic advancement. Therefore, we posit the following hypotheses:

Hypothesis 2: By integrating e-commerce practices, the industry can bolster ecological oversight and contribute to a more robust collective efficiency of green resources.

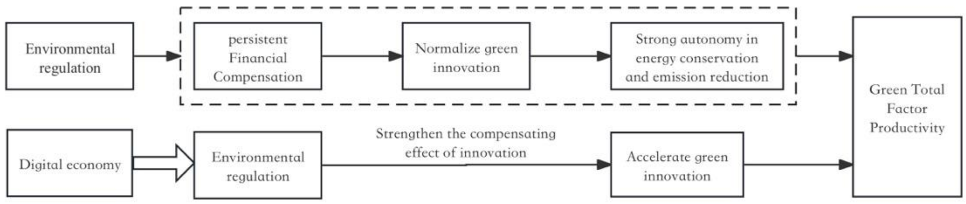

Fig. 1. Oversight structure for ecology, the sector involving e-commerce and the cooperative efficiency of green resources.

3 Empirical Models

3.1 Variable Design

Accurately assessing the unexpected output in the industrial environment is the core of effective measurement of the company's green business performance. Tone[11] proposed the SBM-DDF model to evaluate the change in the ratio of industrial input to production in an ineffective control unit. Compared with the single-direction distance function, the proposed method can identify the non-zero relaxation term and rigorously judge the functionality of industrial green development. In this paper, the top-tier SBM effectiveness model and GML index are used to evaluate the level of industrial collective green resource effectiveness by using Max DEA 9.0 software. The specific design of the description is the listed model:

$$min\varphi = \frac{1/M\sum_{t=1}^{T}\sum_{m=1}^{M}(\bar{x}/x_{qm})}{1/(N+1)(\sum_{t=1}^{T}\sum_{n=1}^{N}\frac{\bar{y}}{y_{qm}}+\sum_{t=1}^{T}\sum_{i=1}^{I}\bar{b}/b_{qi})} \quad (1)$$

$$\text{s.t.}\begin{cases} \bar{x} \geq \sum_{t=1,\neq p}^{T}\sum_{r=1,\neq q}^{Q}\lambda^{t}x_{rm}^{t}, \ \bar{x} \geq x_{qm}, m = 1,\dots,M \\ \bar{y} \leq \sum_{t=1,\neq p}^{T}\sum_{r=1,\neq q}^{Q}\lambda^{t}y_{m}^{t}, \ \bar{y} \leq y_{qn}, n = 1,\dots,N \\ \bar{b} \geq \sum_{t=1,\neq p}^{T}\sum_{r=1,\neq q}^{Q}\lambda^{t}b_{ri}^{t}, \ \bar{b} \geq b_{qi}, i = 1,\dots,I \\ \sum_{r=1}^{Q}\lambda_{r}^{t} = 1, \lambda_{r}^{t} \geq 0, \ r = 1,\dots,Q \end{cases}$$

The depicted equation, φ symbolizes the assessment of efficient green growth for the q choice formulation body within the timeframe p under the framework of worldwide fabrication methods and flexible remuneration. The weight of incoming and outgoing values for the r selection oversight entity during the appointed term t is denoted by λ_{r}^{t}. Specifically, the insertion elements are represented by x, where $x=(x_1,x_2,\dots,x_N)\in R_{+}^{N}$; the envisioned yield is denoted by y, where $y=(y_1, y_2,\dots,y_M)\in R_{+}^{M}$; and the outcome that was not previously considered is represented by b, where $b=(b_1,b_2,\dots,b_I)\in R_{+}^{I}$.Subsequently, the Malmquist DEA index method is employed to delve into shifting dynamics in green total factor production efficiency. Equation (2) presents the Malmquist DEA index model, along with its decomposition model, the Malmquist exponential model for the period, time from *t* to *t+1* requires refinement in its language expression and its corresponding decomposition. This approach involves the decomposition of alterations in the overall efficiency of productivity encompassing a range of modifications into the capacity to efficiently utilize existing factors and the extent of production technology innovation, all while the scale reward remains constant. This decomposition specifically encompasses changes in technological efficiency *(Effch*) and technological progress (*Techch*) [12].

$$GTFP_t^{t+1} = \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}}$$
$$= \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{(}(x^t, y^t)}$$
$$= Effch \times Techch \qquad (2)$$

In the above formula: $GTFP_{t+1}$The collective green resource effectiveness variation gauge is the options administration entity which reflects the dynamic changes of the collective green resource effectiveness production efficiency in different periods; D^t and D^{t+1} are modifications in technical aspects from time *t* to *t+1*; The input-output vectors are(x^t, y^t), (x^{t+1}, y^{t+1}), in the prescribed order, which symbolizing the inflow and outflow of options decision group within the designated time frame *t* and *t+1* periods.

The above indicators for measuring industrial collective green resource effectiveness (GTFP) mainly include: industrial input factors, industrial expected output, and industrial undesired output, the meaning of specific indicators is shown in Table 1.

Table 1 Reception-transmission benchmarks.

First Category Indicator	Second Category Indicator	Indicator Meaning
Industrial input factors	Labor input	Number of industrial employees in urban areas ((myriad people)
	Capital Investment	The combined immobile assets of industrial enterprises surpass their prescribed proportion (myriad RMB)
	Allocation infusion	Incorporation of Electrical Power in Manufacturing (myriad kWh)
Expected Industrial Output Gross	Output Value Gross	Industrial Production Above Designated Threshold ((myriad RMB)
Industrial Undesired Output	Wastewater Discharge	Industrial Effluent Outflow (ton)
	Sulfur Dioxide Venting	Emissions of sulfur dioxide from industry (ton)
	Soot Emissions	Industrial soot emissions(tons)

3.2 Model Construction

The mainstream method to evaluate legal implications is the DID approach. In light of the study conducted[13], we use this method to analyze the effect of ecological oversight on industrial collective green resource effectiveness. The design model in the subsequent way:

$$Y_{it} = \alpha_0 + \beta_1(\text{treat}_{it} \times \text{time}_{it}) + \sum_{j=1}^{n} \beta_{\text{j}} control_{it} + year_i + city_i + \varepsilon_{it} \qquad (3)$$

For the purpose of minimizing interference caused by heterogeneity aspects in evaluating ecological oversight effects, we introduce period and person-specific fixed effects in the model setting, aiming to be closer to the real policy effect.

Explained variables: the industrial collective green resource effectiveness index (GTFP) of the Yangtze River is evaluated by the top-tier SBM effectiveness model and the GML catalogue (see variable design part of this paper for the specific calculation method).

Explanatory variables: Referring to the existing research methods, the explanatory variables (DID) were set as the treatment group (exposure) and the placebo group (duration), the two were combined as did=treat ×time. Provinces flowing through the four stages of upper, intermediary, and lower stretches of the Yangtze River Basin and estuary are selected for grouping. If the city belongs to one of the above four provinces. Boolean indicator treats if it equals 1, otherwise it equals 0. In terms of time, the timeframe for policy execution grouping dummy temporal variation is set and the environmental protection tax law time is officially implemented in 2018.That is 2014-2018 is taken as before the policy implementation, time is taken as 0 and 2018-2021 is deemed as after policy enactment, time is taken as 1.

Control variables: It is the economic level at the regional scale (GEP), gauged through the calculation of the mean value regional GDP that reflects each's economic development status prefecture-level city; the industrial structure (STR) focuses on the quotient of the additional value of the secondary sector's contribution to the value augmentation of the tertiary sector. Foreign direct investment (FDI) is quantified as the ratio of Proportion of regional gross domestic product derived from foreign direct investment. Technology expenditure (TEC), measured by per capita technology expenditure; fiscal decentralization is evaluated based on the local general public budget revenue-to-expenditure ratio. This metric provides insight into the financial health and sustainability of the government at the local level, the local financial stage of progress (FIN) is ascertained by the share of the loan liabilities held by financial bodies to the deposit balance as the year wraps up.

4 Empirically Derived Findings

4.1 Evaluation of Trend Parallelism

In view of high autonomy of some provincial ethnic autonomous prefectures in policy implementation and restricted access to data, we decided to exclude these areas and finally select the data of 108 cities. For the goal of further scrutiny whether the speculation of the validity of assessing the impact of ecological oversight on the effectiveness of collective green resource management within the industrial framework of the Yangtze River cities', we conduct empirical analysis through the DID method and array of robustness tests. Test scores of Figure 2 Illustrate that the pattern of industrial collective green resource effectiveness among subjects allocated to the experimental and control categories was highly consistent before 2018, and there are significant differences between the two groups after 2018, meeting the parallel trend hypothesis, which provides a basis for using the DID approach to evaluate the ramifications of the policy.

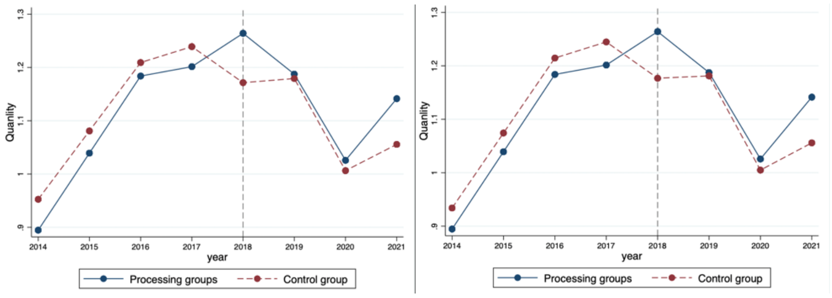

Fig.2 Parallel trend test chart.

4.2 Benchmark Regression

With the parallel trend test criteria fulfilled, the baseline regression analysis is performed with the outcomes presented in Table 2. The study found: that for the explained variable industrial collective green resource effectiveness, the coefficient of excluding the municipality group is lower, indicating that the municipality will indeed interfere with the sample; The parameter of *treat* × *time* shows a considerable upward trajectory. Hypothesis one is established.

Table 2 DID model results.

Variable	GTFP (Municipalities are not excluded)		GTFP′ (Municipalities are excluded)	
	(1)	(2)	(3)	(4)
Treat × *time*	0.0921** (0.0465)	0.0949* (0.0490)	0.0870* (0.0473)	0.0869* (0.0442)
Constant terms	0.8308*** (0.1249)	-0.2673 (1.8182)	0.7856*** (0.1256)	-0.0193 (1.5889)
Control variables	No	Yes	No	Yes
N	864	864	848	848
R^2	0.2676	0.2722	0.2698	0.2746

4.3 Sturdiness Validation

(1) Placebo test

The randomly generated samples of the uppermost, intermediary, and lowermost sections and estuaries are selected for the placebo test, and the error variable $treat_f$ which will not theoretically affect the results, is constructed to replace the real *treat*. Based on the model setting of Eq. (3), 1000 random sampling regressions of industrial collective green resource effectiveness in all regions and excluding municipalities are carried out. Through Figure 3, it can be seen that the randomly generated regression coefficients of determination are concentrated near 0, and the overall distribution is normal and not significant, the sampling coefficients are located on the right side of their baselines, indicating that the sample has no impact on the industrial collective green resource effectiveness, the DID estimation results are robust.

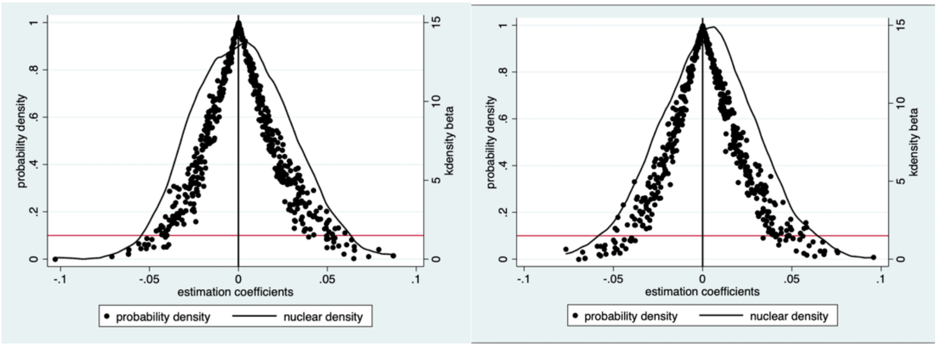

Fig.3 Placebo test.

(2) Counterfactual test

The policy pilot time is fictitious, and the benchmark regression consistency test is carried out one year ahead of the scheduled initiation phase for policy enforcement (i.e., 2017). Insights derived from regression of Table 3 manifest that the coefficients of the reciprocity factor treat × time have not reached a significant level, indicating that before 2018, ecological oversight demonstrated minimal influence on the industrial collective green resource effectiveness of the manipulated group and the unmanipulated group, confirmatory appraisal of the reliability of the previous regression results.

Table 3 Counterfactual test.

Variable	GTFP (Municipalities are not excluded)		GTFP′ (Municipalities are excluded)	
	(1)	(2)	(3)	(4)
Treat × time	0.0753 (0.4812)	0.0768 (0.0505)	0.0664 (0.0489)	0.0674 (0.0515)
Constant terms	0.8313*** (0.1255)	-0.4488 (1.8149)	0.7844*** (0.1262)	-0.1797 (1.5855)
Control variables	No	Yes	No	Yes
N	864	864	848	848
R^2	0.2661	0.2708	0.2683	0.2731

(3) Effects of other policy heterogeneity

To further test, referring to the research methods of scholars such as Shi Dan (2020)[14], The region situated in the Yangtze River as a national metropolitan area selected as a low-carbon demonstration zone(2010) is set as a new processing variable $treat_1$, and assigned to 1 after 2018, and the rest are all 0. The results of the test (see Table 4) establish that the measure of the interaction term treat×time×treat1 between the ecological tariff and the national low-carbon pilot city policy demonstrates a considerable positive correlation with a confidence level of 90% for statistical significance hinting at the idea that the policy combination offers the opportunity for substantial enhancement the regional collective green resource effectiveness (Hypothesis 1 is supported by the evidence).

Table 4 Findings derived from policy heterogeneity.

Variable	GTFP (Municipalities are not excluded)		GTFP′(Municipalities are excluded)	
	(1)	(2)	(3)	(4)
$treat\times time\times treat_1$	0.1353* (0.0718)	0.1359* (0.0691)	0.1320* (0.0719)	0.1324* (0.0690)
Constant terms	0.9209*** (0.0414)	-0.1866 (1.4254)	0.9121*** (0.0416)	-0.3070 (1.4213)
Control variables	No	Yes	No	Yes
N	864	864	848	848
R^2	0.0961	0.1020	0.1009	0.1069

4.4 Inquiry into moderating effects

With the objective of conducting further exploration the realization mechanism of this effect, we construct an index system of the e-commerce sector from five dimensions, entailing information on Internet connectivity, mobile device usage, and workforce composition in the information transmission and technical service industry, the per capita telecommunication business volume, and the urban digital inclusive finance index, this index is embedded in the benchmark model (3) for analysis, and the precise model is structured as stated hereafter:

$$Y_{it} = \alpha_0 + \beta_1(\text{treat}_{it} \times \text{time}_{it} \times \text{digital}_{it}) + \beta_2(\text{treat}_{it} \times \text{time}_{it}) + \beta_3 \times \text{digital}_{it} + \sum_{j=1}^{n} \beta_j control_{it} + year_i + city_i + \varepsilon_{it} \tag{4}$$

In Eq. (4), Y_{it} represents the industrial collective green resource effectiveness, and digital_{it} represents the moderating variables, focusing on the gravity of the coefficients within the interplay component $treat_{it}\times time_{it}\times digital_{it}$, and the definitions of supplementary variables are congruent with Eq. (3). The empirical observations are outlined in Table 5, subsequent to the inclusion of e-commerce sector indicators and the arrangement of cities based on their status as prefecture-level administrative units in the previous we the interaction term coefficient estimate is significantly optimistic, and carries substantial weight level is also increased from 10% to 5%, which means that through refining the magnitude of the e-commerce sector, ecological oversight can be further positively improved to promote the efficiency of industrial collective green resource effectiveness, hypothesis 2 is verified.

Table 5 Review of the determinants: from the perspective of the level of e-commerce sector.

Variable	Baseline regression (GTFP)		Regulatory effect (GTFP)	
	(1) not excluded	(2) Municipalities	(3) not excluded	(4) Municipalities
$treat \times time$	0.0949* (0.0490)	0.0869* (0.0442)		
$treat \times time\times digital$			0.6715** (0.2714)	0.6491** (0.2744)
Constant terms	-0.2673 (1.8182)	-0.0193 (1.5889)	-0.5540 (1.4597)	-0.2481 (1.2594)
N	864	848	864	848
R^2	0.2722	0.2746	0.2741	0.2764

5 Conclusions

Enhancing the overall effectiveness of collective green resources stands as a pivotal objective within the realm of ecological oversight. It serves as an unwavering driving force propelling excellence-driven growth in the Yangtze River Belt. Building upon prior research, this paper integrates ecological oversight, the e-commerce sector, and the efficacy of collective green resources into a unified theoretical analysis framework. Conducting an analysis with panel data derived from 108 cities with prefectural status located in the Yangtze River Belt spanning the years 2014 to 2021, a difference-in-difference model is implemented to empirically assess the situation of ecological oversight.

Furthermore, from the perspective of impact mechanisms, a positive correlation emerges—indicating that regions with developed states in the e-commerce sector contribute significantly to fostering green and high-caliber economic growth. This phenomenon underscores the reinforcing role of ecological oversight in enhancing the effectiveness of collective green resources.

References

[1] Huang Heping, Li Ying (2023). Research scrutinizing how environmental tax reform impacts energy utilization performance and the associated mechanisms [J]. Chinese Environmental Science, 43(7): 3821-3834.

[2] Zhu Dongbo (2020). Ecological oversight, technological modernization and the green China's revolutionary change industrial structure [J]. Industrial Technology and Economics, 39(10): 57-64.

[3] Dai Kuizao, Luo Yuhan (2022). Ecological oversight, government science and the collaborative effectiveness of green resource utilization in industry with technological support [J]. Statistical Research, 39 (4): 49-63.

[4] Hao Huayong (2022). Research on the effect and mechanism of strategic cutting-edge developments drawing from the Yangtze River Economic Zone In light of the double difference model [J]. Hubei Social Sciences, 61-70.

[5] Li Zhiguo, Yang Yahan, Zhao Yuanchun (2022). Is regional carbon emission intensity influenced by the competitive dynamics among local governments? [J]. Economics and Management Review, 38(2):136-146.

[6] Lai Xiaodong, Li Zhen, Zheng Panpan (2022). Ecological oversight, coverage in the news and collective green resource effectiveness: analysis from provincial panel data [J]. Ecological Economics, 166.

[7] Zhou Xiaohui, Liu Yingying, Peng Liuying (2021). Digital economic development and collective green resource effectiveness improvement [J]. Shanghai Economic Research, 51-63.

[8] Liu Weilin, Wang Yibin (2022). Research on the effects and mechanisms of the e-commerce sector Promoting sustainable growth and excellence in urban green development [J]. Southern Economy, 73-91.

[9] Zhu Xian, Ma Yingge (2022). Analysis of the repercussions of the e-commerce sector on changes in collective green resource effectiveness [J]. Economic Issues, 11,1-11.

[10] Luo Jun, Qiu Haitong (2022). An analysis of the spatial dynamics in which the urban e-commerce sector propels the green evolution of the manufacturing industry [J]. Economic Geography, 42, 13-22.

[11] Tone, K., & Tsutsui, M. (2010). An epsilon-based measure of efficiency in DEA-A third pole of

technical efficiency. European Journal of Operational Research, 207(3), 1554-1563.
[12] Färe R, Grosskopf S, Lindgren B, et al (1992). Swedish Pharmacies' Productivity Changes During 1980-1989: A Non-Parametric Malmquist Analysis [J]. Journal of Productivity Analysis, 3(1),85-101.
[13] Wang Guijun, Lu Xiaoxiao (2019). “The Silk Road Economic Belt and the 21st-Century Maritime Silk Road” Chinese Business Proactiveness and Enhancement [J]. China Industrial Economy, 390, 43-61.
[14] Shi Dan, Li Shaolin (2020). Energy and emissions trading scheme utilization efficiency measurement and Factual evidence concerning cities positioned at the prefecture level and above [J]. Economic Dynamics of Chinese Industry, 390,5-23.