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Do Central Inspections of Environmental Protection Affect the Efficiency of the Green Economy? Evidence from China's Yangtze River Delta

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Abstract: As an important part of China's ecological civilization, the impact of the Central Inspections of Environmental Protection (CIEP) on the development of a green economy has been widely recognized. This article uses the first round of the Central Inspections of Environmental Protection (CIEP) and the "look-back" in cities above the prefecture level in China's Yangtze River Delta as a quasi-natural experiment to construct more scientific green economic efficiency indicators based on OH (2010), and employs a multi-period spatial DID (difference-in-differences) model to empirically investigate the impact of the CIEP on the urban green economic efficiency. This study confirms that: (1) The Central Inspections of Environmental Protection have a significant contribution to the green economic efficiency of cities, and the "look-back" is of great significance to the long-term green development of cities. (2) The Central Inspections of Environmental Protection have had a positive impact on the building of a pro-clear government–business relationship in coastal and riverine areas, promoting the application of green technology research and development, and, thus, improving the green economic efficiency of cities. (3) Under the constraints of the central environmental protection inspection system, the southern Jiangsu region has been effective in promoting the green transformation of enterprises to enhance the efficiency of the city's green economy due to its location endowment and historical tradition of opening ports and trading in the late Qing Dynasty. (4) Under the pressure of environmental regulation, some enterprises chose to relocate their production to non-inspected areas, which had a negative spillover effect on the green economic efficiency of the cities they moved into. Policy Implications: The impact of central environmental inspections on the efficiency of urban green economies varies from time to time and place to place, and it is important to regulate the use of administrative resources and strengthen inter-provincial coordination to promote synergy and cooperation across provincial environmental inspection systems. This paper provides ideas for understanding the logical starting point for the implementation of the central environmental inspection system, and for better promoting the green transformation and high-quality development of regional economies based on national characteristics.

Keywords: Central Inspections of Environmental Protection; green economic efficiency; "look-back"; regional heterogeneity; spatial spillover; distortion effect

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1. Introduction

The concept of "green development" was first introduced by the United Nations Development Program in 2002 and is widely regarded by society as the ideal path to achieve the organic integration of the economy and environment (Adam, 2009) [1]. Since 2006, China has been the world's largest emitter of carbon emissions, and with the positive progress of the domestic economic transformation, both total carbon emissions and carbon emissions per unit of GDP have slowed down to a certain extent. To this end, China proposed, in

September 2020, the "double carbon" target of "peak carbon" by 2030 and "carbon neutral" by 2060, which is both a solemn commitment to the world and a timetable and roadmap for China's environmental governance and green development. The report of the 20th Party Congress emphasizes that "Chinese modernization is a modernization in which people and nature live in harmony" and that "we must firmly establish and practice the concept that green water and green mountains are golden mountains and plan development in the context of the harmonious coexistence of people and nature". Putting in hard work to solve environmental problems is both a highly sensitive political proposition and an important area of institutional innovation for Chinese-style governance modernization [2].

In fact, the Central Environmental Protection Inspectorate is an important institutional design made by the Central Government to promote ecological protection and green development. In July 2015, the Central Leading Group for Comprehensively Deepening Reform considered and adopted the Environmental Protection Inspectors Program (for Trial Implementation), an innovative proposal to build an environmental protection inspection mechanism. Compared to previous environmental governance initiatives, such as the "Ten Articles of the Atmosphere" [3], "Trading of Pollution Rights" [4] and "Environmental Protection Talks" [5], the Central Inspections of Environmental Protection have authoritative and mandatory features, with a more stringent accountability mechanism, and an innovative governance practice in China's green system from "supervising enterprises" to the party and government being equally responsible. In December 2015, the Central Inspections of Environmental Protection launched a pilot scheme in Hebei Province, and, in August 2017, completed the first round of environmental protection inspections, covering 31 provinces and municipalities. In 2019, the central government studied and introduced China's first party regulation in the field of ecology and environment, the Central Ecological and Environmental Protection Inspectors' Regulations, which stipulate that within each term of the party's Central Committee, the party committees and governments of all provinces and municipalities, relevant departments of the State Council and relevant central enterprises shall be routinely inspected and, where appropriate, rectified via "look back" and special inspections. This provides institutional safeguards for the normalization of the Central Inspections of Environmental Protection.

In terms of the practice of central environmental inspections, the focus includes three stages, including the stationing of inspections, the placing of inspectors in local municipalities and the sorting and analysis of the results. The central government selects the head of the inspection team (the deputy head of the team is usually the current deputy head of the state environmental protection department) and leads the team into the provinces and municipalities to carry out environmental inspection work for one month. During their stay, the inspection teams combine reports from the public, information review and on-site spot checks to inspect outstanding environmental problems in the development process of localities. Phenomena such as inaction on the part of party committees and governments in environmental protection are also the focus of the Central Inspections of Environmental Protection. After the completion of the inspection, the inspection team is given a deadline to complete the inspection report and provide feedback to the provincial party committees and governments, which will submit the rectification and reform plan to the State Council for review within 30 working days and make the environmental rectification plan and its implementation available to the public.

In the context of the accelerated construction of a modern Chinese green institutional system, examining the impact of the Central Inspections of Environmental Protection on the green economic efficiency at the city level is of great theoretical and practical value in grasping the practical effects of the green premium (meaning the absolute difference between how much people should pay for fossil fuel-based energy and renewable energy) [6] and green economic development under the constraints of the environmental protection inspection system, as well as in formulating and improving Chinese environmental public policies in the next phase. The purpose of this paper is to answer the following questions: firstly, what is the level of efficiency of China's green economy, represented by the

Yangtze River Delta region, under the central environmental protection inspection system? Secondly, does the central environmental inspection system have an impact on the green economic efficiency of the Yangtze River Delta cities? Finally, if the central environmental inspection system has an impact on the green economic efficiency, does this impact vary over time and across regions, i.e., is the impact heterogeneous over time and space?

The innovations include the following three parts. Firstly, the focus on the Central Inspections of Environmental Protection, an important institutional arrangement for promoting ecological protection in China and its economic impact, has inspired ideas for further understanding the logic of ecological governance in China. Second, it focuses on the Yangtze River Delta, one of the most dynamic, open and innovative regions in China, and selects a more appropriate research case for a better analysis of the policy effects of the Central Inspections of Environmental Protection. Third, a diverse and heterogeneous discussion of the role of the Central Inspections of Environmental Protection on the urban green economic efficiency, both at the temporal and spatial levels, provides an empirical basis for better improving central environmental protection inspection policies.

The research structure of this paper includes the following three main aspects. It begins with a literature review of existing studies, then constructs core indicators and sets up a multi-period spatial DID model, and, finally, conducts a focused analysis on the temporal variability, locational variability, geographical variability and spillover variability of the impact of the Central Inspections of Environmental Protection on the green economic efficiency, respectively, in order to examine the possible impact of the Central Inspections of Environmental Protection on the urban green economic efficiency.

2. Literature Review

From the literature, environmental governance policies are divided into two main categories: administrative and market-based. From theoretical analysis, market-based environmental governance policies, such as carbon emission rights, emissions trading and pollution taxes, can help reduce pollution emissions and promote technological innovation [7] and are ideal for combating environmental pollution, but empirical evidence shows that the improvement of environmental problems in the US and Canada is mainly attributed to strictly enforced environmental regulations and accompanying provisions [8]. The limited role of market transactions in reducing pollutant emissions in China [9] means there is a need for greater environmental enforcement to achieve effective governance. Although studies have confirmed that administrative environmental policies have been a key factor in the sustained improvement in environmental quality since China's reform and opening up [10], the sustainability of administrative policies has been questioned, and the reduction in pollutant emissions may only be short-term [11], with the possibility of a significant rebound in pollution after the relaxation of environmental regulations [12]. In addition, under the "pollution sanctuary effect" hypothesis, the analysis of policy games between local governments may also lead to difficulties in the implementation of national-level environmental regulation policies [13]. Based on the above considerations, the selection of appropriate and effective environmental policy instruments is a challenging task. In fact, the combination of the high cost of implementing environmental regulations and the significant variation in pollution emissions across sectors and regions has led to the uneven implementation of environmental policies. For example, Gibson evaluated the effectiveness of the Clean Air Act in the US and found that companies changed the form of their pollution emissions under the system, impacting on land and water resources [14]. The Clean Water Act is not as effective as the Clean Air Act [15].

The main reason for the emergence of the central environmental inspection system is the information asymmetry between the central government and local authorities, and the resulting incentive incompatibility of the principal–agent relationship between the two levels. On the one hand, the central government has "delegated responsibility but not power" to local governments [16] and local governments are not only the implementers of central government policies, but also the providers of local economic and social development and public services [17]. This poses a serious challenge to local governments in terms of the quality and quantity of policy objectives, and the further down the hierarchy you go, the more difficult it becomes. On the other hand, economic development goals are still an important criterion when examining officials [18], which has led to a tendency for local governments to "conspire" with local enterprises after environmental protection mandates have been issued [19], using the advantage of local information, and different levels of local governments may form "offensive and defensive alliances" between themselves [20]. These coping strategies may weaken the implementation of central environmental policies at the local level, and to a certain extent affect the spatial layout of local productivity and the efficiency of the green economy. From an empirical study, W Wang et al. [21] (2021) used data from 290 prefecture-level cities in China to evaluate the air improvement effects of the central environmental inspection mechanism, and found that under conditions of information symmetry, the central government can design incentive contracts to enable local governments to reach the Pareto optimal level of effort. Within a very short period of time, both the first round of environmental supervision and the return visit of environmental supervision significantly improved the air quality and significantly reduced major single pollutants such as $PM_{2.5}$ and PM_{10}. Compared with the first round of environmental protection inspections and environmental protection inspection returns, the latter had higher levels of air pollution reduction and better results. Ruxin Wu et al. [22] (2019) used the effect of central environmental protection inspections on air pollution management as an example and used regression discontinuity to find that central environmental protection inspections have a positive effect on the air quality index (AQI), but this effect is only short-term and unsustainable. In addition, there are inter-provincial differences. Because of the performance and promotion of local officials, and for accountability reasons, specific environmental assessments by the central government through local governments are more effective than central environmental inspections. Ruoqi Li et al. [23] (2020) found that the gradual improvement in the scientific level of the accountability system of the central environmental inspection team, with more precise accountability targets, improved the environmental quality and had a. Zhigao Luo et al. [24] (2019) extracted environmental intention words from Chinese central and provincial government work reports through data mining from the perspective of environmental federalism, and used an instrumental variables approach to conduct an empirical experiment on the battle between the centralization and decentralization of environmental governance. The results show that there is a negative correlation between the central government's environmental governance intentions and the provincial environmental quality, while there is a positive correlation between the provincial government's environmental governance intentions and the provincial environmental quality. Environmental centralization, together with its political, economic and cultural factors, has transformed provincial governments into proponents of environmental pollution, while the central government's ongoing campaign to check environmental protection has forced provincial governments to play a role to some extent.

From the above analysis of the literature, it can be seen that the Central Inspections of Environmental Protection are a large-scale governance activity in China to deal with environmental governance, and an integrated innovation of environmental governance tools to promote the modernization of the harmonious coexistence between human beings and nature. Under the "party-run" national vertical management structure [25], the central government is committed to holding local governments accountable for the environmental quality of their regions through the environmental inspection system, adopting a multi-principal governance approach that is "party-led, business-led and socially engaged". However, studies have mainly focused on the impact of the Central Inspections of Environmental Protection on environmental quality improvement but lacked the impact on the quality development of the green economy, especially the efficiency of the green economy. In terms of the practical effects of the inspections, did the first round of the Central Inspections of Environmental Protection and the 'look-back' really promote high-quality regional development and enhance the green economic efficiency? Taking the Yangtze

River Delta region of China as an example, this paper examines the heterogeneous effects of the first round of the Central Inspections of Environmental Protection and the 'look-back' as a quasi-natural experiment, using a multi-period spatial DID model to test the effects of the Central Inspections of Environmental Protection on the urban green economic efficiency.

3. Models, Methods and Data

3.1. Green Economy Efficiency Measurements

The exclusion of resource factors does not fully reflect the characteristics of economic development. Therefore, some scholars have incorporated resource and environmental factors into productivity measurement models and used different methods to measure green economic efficiency [26–32]. For example, in the work of Chung et al. (1997) [33] measuring total factor productivity (TFP) in Swedish pulp mills, the first SBM (Slacks-Based Measure) model with pollution emissions as a non-desired output and a directional distance function was developed. Tone (2003) [34] innovated a hybrid distance function EBM (Epsilon-Based Measure) model that incorporates slack variables into the function and considers both a CCR (A. Charnes & W.W. Cooper & E. Rhodes) model with radial factors and a non-radial SBM model with slack variables. The non-radial SBM model weakens the measurement error that may arise from a single distance function. Following OH (2010) [35], the results of the GML (Global Malmquist–Luenberger) index of the SBM model were used to characterize the green economic efficiency of the city. In this regard, the mathematical expression of the SBM model is

$$\rho^* = \min \frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\overline{x}_i}{x_{i0}}}{\frac{1}{S_1+S_2}\left(\sum_{r=1}^{S_1}\frac{\overline{y}_r^g}{y_{r0}^g}+\sum_{r=1}^{S_2}\frac{\overline{y}_r^b}{y_{r0}^b}\right)}, s.t. \begin{cases} \overline{x} \geq \sum_{j=1,\neq k}^{n}\theta_j x_j \\ \overline{y}^g \leq \sum_{j=1,\neq k}^{n}\theta_j y_j^g \\ \overline{y}^b \geq \sum_{j=1,\neq k}^{n}\theta_j y_j^b \\ \overline{x} \geq x_0, \overline{y}^g \leq y_0^g, \overline{y}^b \geq y_0^b, \overline{y}^g \geq 0, \theta \geq 0 \end{cases} \tag{1}$$

$$x \in R^m, y^g \in R^{S_1}, yb \in R^{S_2}$$

$$X = [x_1, x_2, \ldots, x_n] \in R^{m\times n}, Y^g = [y_1^g, y_2^g, \ldots, y_n^g] \in R^{S_1\times n}, Y^b = [y_1^b, y_2^b, \ldots, y_n^b] \in R^{S_2\times n}$$

The SBM model is premised on the assumption of constant size, represents input, desired and undesired output slack, and the p objective function value characterizes the decision unit efficiency value.

The mathematical expression for the GML index is

$$\begin{aligned} GML^{t,t+1} &= \frac{1+\vec{D}_o^G(x^t,y^t,b^t;y^t,b^t)}{1+\vec{D}_o^G(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})} \\ &= \frac{1+\vec{D}_o^G(x^t,y^t,b^t;y^t,b^t)}{1+\vec{D}_o^G(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})} \times \frac{1+\vec{D}_o^G(x^t,y^t,b^t;y^t,b^t)/1+\vec{D}_o^G(x^t,y^t,b^t;y^t,b^t)}{1+\vec{D}_o^G(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})/1+\vec{D}_o^G(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})} \\ &= \frac{TE^t(x^t,y^t,b^t;y^t,b^t)}{TE^{t+1}(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})} \times \frac{BPG^{G,t}(x^t,y^t,b^t;y^t,b^t)}{BPG^{G,t+1}(x^{t+1},y^{t+1},b^{t+1};y^{t+1}b^{t+1})} \\ &= GMLEC^{t,t+1} \times GMLTC^{t,t+1} \end{aligned} \tag{2}$$

The GML index can be decomposed into technical efficiency (EC) and technical progress (TC). $\vec{D}_o^G(x^t,y^t,b^t;y^t,b^t)$, $\vec{D}_o^G(x^{t+1},y^{t+1},b^{t+1};y^{t+1},b^{t+1})$ denote the efficiency values of the decision unit in period t and period $t+1$ in period t, respectively.

In the measurement of the urban green economy efficiency, the selection of input indicators includes: (1) Capital input. The physical capital stock of the city is selected for measurement. Due to the lack of corresponding statistical indicators, this paper uses the method of Shan, Haojie (2008) [36], using the data of the fixed asset investment flow of each city and deflating it, with 2010 as the base period, in which the depreciation rate is set at 10.96%. (2) Labor input. The total number of employees in the secondary and tertiary industries was selected as the indicator of the labor force in a particular city. (3) Resource and energy inputs. Total water supply and social electricity consumption were chosen as the indicators for measuring the resource and energy inputs in the economic development of the city, respectively. (4) Desired output. Considering the level of economic development and the quality of life of urban residents as the main indicators of the desired output, the real gross regional product and the greening coverage of built-up areas were selected as the proxy variables for the above two indicators, respectively. (5) Non-desired output. Focusing on the selection of industrial smoke emissions, industrial wastewater emissions, industrial SO_2 emissions and $PM_{2.5}$ concentrations as indicators to measure the pollution situation in the process of urban economic development. From the kernel density plot (Figure 1), although the measured green economic efficiency of the Yangtze River Delta cities shows a right-skewed distribution overall, the difference with the normal distribution (Normal distribution) is not obvious, and the measurement results generally meet the statistical requirements.

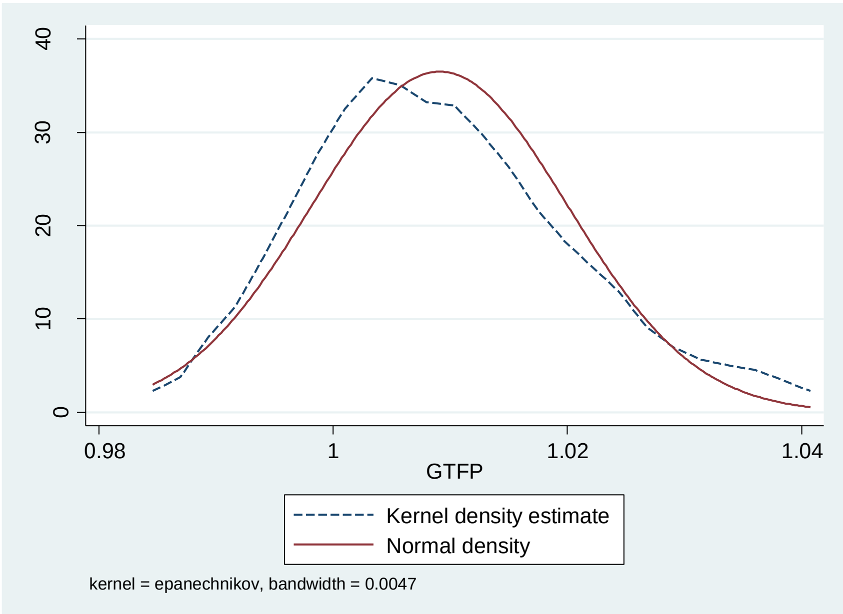

Figure 1. Kernel density diagram of urban green economic efficiency measurement results.

3.2. Central Inspections of Environmental Protection

The first round of the Central Inspections of Environmental Protection consisted of four batches, of which the first batch started in July–August 2016 and involved eight provinces and municipalities, including Inner Mongolia, Heilongjiang, Jiangsu, Jiangxi, Henan, Guangxi, Yunnan and Ningxia. April–May 2017 involved seven provinces and municipalities, including Tianjin, Shanxi, Liaoning, Anhui, Fujian, Hunan and Guizhou, and the fourth batch started in August–September 2017, involving eight provinces and municipalities, including Jilin, Zhejiang, Shandong, Hainan, Sichuan, Tibet, Qinghai and Xinjiang. After the completion of the first round of inspections in 2018, 20 more provinces and urban areas were "looked back", including the fourth round of the Central Inspections of Environmental Protection, from 5 June to 5 July 2018, which carried out a "look back" at the rectification and reform of the first round of the Central Inspections of Environmental Protection in Jiangsu Province. This paper will, therefore, look back at the 2016 reports of the Yangtze River Delta region. Therefore, in this paper, the 13 municipalities in Jiangsu and Shanghai, which were inspected by the Central Inspections of Environmental Protection in 2016 in the Yangtze River Delta region, are used as the treatment group of the multi-period double difference model, while the other 27 municipalities are used as the control group of the study.An analysis of the characteristics of the cities in the Yangtze River Delta involved in the first round of Central Environmental Protection Inspectors is shown in Table 1.

Table 1. Analysis of the characteristics of the cities in the Yangtze River Delta involved in the first round of the Central Inspections of Environmental Protection (batches 1 and 2).

City	Experimental Group	Control Group	Are Coastal and Riverine	Geographical Area	City	Experimental Group	Control Group	Are Coastal and Riverine	Geographical Area
Shanghai	Yes	No	Yes	–	Quzhou	No	Yes	No	–
Nanjing	Yes	No	Yes	Sunan	Zhoushan	No	Yes	Yes	–
Wuxi	Yes	No	Yes	Sunan	Taizhou	No	Yes	Yes	–
Xuzhou	Yes	No	No	Northern Sudan	Lishui	No	Yes	No	–
Changzhou	Yes	No	Yes	Sunan	Hefei	No	Yes	No	–
Suzhou	Yes	No	Yes	Sunan	Huaibei	No	Yes	No	–
Nantong	Yes	No	Yes	Suzhou-China	Bozhou	No	Yes	No	–
Lianyungang	Yes	No	Yes	Northern Sudan	Cebu	No	Yes	No	–
Huai'an	Yes	No	No	Northern Sudan	Bengbu	No	Yes	No	–
Yancheng	Yes	No	Yes	Northern Sudan	Fuyang	No	Yes	No	–
Yangzhou	Yes	No	Yes	Suzhou-China	Huainan	No	Yes	No	–
Zhenjiang	Yes	No	Yes	Sunan	Chuzhou	No	Yes	No	–
Taizhou	Yes	No	No	Suzhou-China	Lu'an	No	Yes	No	–
Suqian	Yes	No	No	Northern Sudan	Ma On Shan	No	Yes	Yes	–
Hangzhou	No	Yes	Yes	–	Wuhu	No	Yes	Yes	–
Ningbo	No	Yes	Yes	–	Xuancheng	No	Yes	No	–
Wenzhou	No	Yes	Yes	–	Tongling	No	Yes	Yes	–
Huzhou	No	Yes	No	–	Chizhou	No	Yes	Yes	–
Jiaxing	No	Yes	Yes	–	Anqing	No	Yes	Yes	–
Introduction	No	Yes	Yes	–	Huangshan	No	Yes	No	–
Jinhua	No	Yes	No	–	–	–	–	–	–

3.3. Control Variables

Following Taskin and Zaim (2001) [37] and other studies, control variables such as firm size (X1), per capita savings (X2), government influence on the economy (X3), strength of foreign ties (X4), per capita investment in education (X5) and unemployment insurance coverage (X6) were selected to be included in the model for econometric estimation. The higher the savings, the lower the demand for low-quality goods and services and the lower the tolerance for counterfeit products, forcing producers and operators to consciously keep their promises and improve the quality of goods and services. In the case of increasing efforts to build an honest government, the higher the degree of government influence on the economy, the stronger the demonstration drive on the market society and the greater the role in enhancing the city's business credit environment. The higher the intensity of external linkages, the greater the focus on benchmarking international rules to improve the city's business environment. In addition, investment in education is closely related to residents' awareness of integrity, and the improvement and expansion of unemployment insurance is also conducive to stabilizing the market development expectations of micro- and small enterprises and individual entrepreneurs and other micro-operators, and optimizing the city's business credit environment.

The scale of enterprises (X1) is measured by the ratio of industrial assets above the scale to the number of industrial enterprises above the scale; the government's influence on the economy (X3) and the strength of external ties (X4) are measured by the general budget expenditure of the local finance and the proportion of the total import and export of goods to the regional GDP, respectively; the per capita savings of residents (X2), the per capita investment in education (X5) and the unemployment insurance coverage rate (X6) are measured by the ratio of the year-end balance of urban and rural residents' savings, education expenditure and unemployment insurance coverage to the total population. In summary, the inclusion of institutions, factors and the environment as control variables is used to mitigate the problem of missing explanatory variables.

3.4. Description of Data

The research object of this paper is 41 cities above prefecture level in the Yangtze River Delta region, and the research interval is set from 2011 to 2019, considering the research needs and data availability. The PM2.5 concentration data were obtained from the satellite remote sensing data published by NASA, and the 1:4 million Chinese basic geographic information data provided by the National Center for Basic Geographic Information were cropped to obtain the average PM2.5 concentration values of the cities in the past years. For missing data, the interpolation method was used to process the data.

3.5. Measurement Models

In examining the impact of the Central Inspections of Environmental Protection on the efficiency of the green economy in cities, the traditional multi-period DID model has certain advantages for the analysis of the effect of policy implementation, with cities belonging to the treatment group when they are affected by policy implementation and to the control group when they are not affected by policy implementation; at the same time, a time dummy variable for policy implementation is introduced, with the year before policy implementation taking the value of 0 and the year after policy implementation taking the value of 1. The basic model formulation is as follows.

$$GTFP_{it} = \beta_0 + \sum_{k=1}^{K} X_{it,k}\beta_k + DID_{it}\beta_{k+1} + \varepsilon_{it} \tag{3}$$

where $GTFP$ represents the level of the green economy efficiency and β represents the regression coefficient of each variable. t represents the time of implementation of the CIEP and takes values between [1, T], T = 10. $X_{it,\,k}$ represents the k control variables in the model and takes values between [1, K], K = 8. DID_{it} represents the dummy variable interaction term, which is the policy effect parameter to be estimated, and is obtained by multiplying the values of the dummy variables for the group attributes and the time of the CIEP and by centralization. The dummy variables taken for the group attributes and the time of the CIEP are multiplied together and centralized. ε_{it} represents the random error term.

However, the magnitude of the effect of the Central Inspections of Environmental Protection on the green economic efficiency of cities, in the context of the construction of a large national unified market, gradually weakens the influence of provincial administrative fragmentation on the development of the market economy, and the green development of cities is increasingly influenced by neighboring cities, especially in the context of the integrated development of the Yangtze River Delta. Rising as a national strategy, the spatial interaction of the Central Inspections of Environmental Protection in the implementation process will also be more obvious. Spatial correlations of the core variables confirm these conjectures, with global univariate Moran indices of 0.6672 and −0.1511 for the interaction term and green economic efficiency, respectively, and a global bivariate Moran index of 0.0457 for the interaction term and green economic efficiency in 2019 (Table 2), confirming that there is a significant spatial correlation between the urban green economic efficiency and the effect of the central environmental inspections on the implementation of the green economic efficiency. Both have a more significant spatial correlation. In this case, the above traditional multi-period DID model may become inapplicable to the analysis of policy effects, and spatial factors must be incorporated into the model in order to more scientifically measure and analyze the possible impact of the Central Environmental Protection Inspectorate on the efficiency of the green economy.

Table 2. Spatial correlation tests for policy implementation effects: the Moran index.

Measurement Indicators	2015	2016	2019
Green economic efficiency	−0.0627	−0.1061	−0.1511
Interaction term (DID) × Green economic efficiency	−0.2004	−0.0346	0.0457

In view of this, a more scientific multi-period spatial DID model is constructed on the basis of the traditional multi-period DID model, taking into account the requirement of spatial multi-collinearity avoidance, to conduct a targeted analysis of the impact of the Central Inspections of Environmental Protection on the efficiency of the urban green economy. In particular, the spatial lagged model (SLM) is formulated as

$$GTFP_{it} = \sum_{it=1}^{NT} \rho_{SLM}(\xi \otimes \pi)_{it,it} GTFP_{it} + \beta_0 + \sum_{k=1}^{K} X_{it,k}\beta_k + DID_{it}\beta_{k+1} + \varepsilon_{it} \quad (4)$$

The spatial lag model (SEM) is formulated as

$$GTFP_{it} = \beta_0 + \sum_{k=1}^{K} X_{it,k}\beta_k + DID_{it}\beta_{k+1} + \mu_{it} \quad (5)$$

$$\mu_{it} = \sum_{it=1}^{NT} \rho_{SEM}(\xi \otimes \pi)_{it,it}\mu_{it} + \varepsilon_{it} \quad (6)$$

where ξ and π denote the temporal and spatial weight matrices after row normalization, respectively. $\xi \otimes \pi$ represents the endogenous spatio-temporal weight matrix, which is measured according to the city–location relationship, and the matrix element is 1 if the two cities are adjacent in a spatial location and 0 otherwise. In addition, i = 1, 2, . . . , N, N = 41, denotes the 41 cities above prefecture level in the Yangtze River Delta region; ρ represents the spatial correlation coefficient in the spatial econometric model, and represents the normally distributed random error vector.

4. Estimation of Measurement Results

4.1. Central Inspections of Environmental Protection and Green Economy Efficiency: Time Impact Variability

Based on the spatial correlation test of the core variables, the spatial DID method was used to test the possible impact of the Central Inspections of Environmental Protection on the green economic efficiency of the city, and the estimation results are reported in Table 3, where models (1)–(3) and (6)–(9) represent the regression results before and after the Central Inspections of Environmental Protection, respectively, and models (4)–(6) represent the results of the benchmark analysis, reflecting the impact of the Central Inspections of Environmental Protection on the city's green economic efficiency in general, and OLS, SLM and SEM denote the ordinary least squares model, spatial lag model and spatial error model, respectively. Models (3), (5) and (9) were selected for further analysis by combining the magnitude of the Log-likelihood, AIC and SC values, respectively.

Table 3. Central environmental inspections and green economy efficiency: variability in time impact.

	Before_2015			**Benchmarking_2016**			**After_2019**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Model type	OLS	SLM	SEM	OLS	SLM	SEM	OLS	SLM	SEM
Interaction items (DID)	−0.014 (−1.085)	−0.011 (−0.911)	−0.013 * (−1.39)	0.017 (1.138)	0.025 ** (1.878)	0.012 (1.092)	−0.006 (−0.441)	−0.004 (−0.28)	−0.004 * (−0.468)
Control variables	Control	Control	Control	Control	Control	Control	Control	Control	Control
R-squared	0.126	0.132	0.253	0.193	0.259	0.264	0.175	0.178	0.378
Log-likelihood	90.422	90.576	92.185	89.106	90.822	90.2	90.883	90.948	94.463
AIC	−160.845	−159.152	−164.371	−158.212	−159.645	−160.4	−161.766	−159.897	−168.925
SC	−143.709	−140.302	−147.235	−141.076	−140.796	−143.264	−144.631	−141.048	−153.789

Note: **, * denote 5%, 10% significance levels, respectively; t/z values in parentheses. Regression results for control variables are omitted for space constraints and are available from the authors upon request.

The results show that the treatment effect coefficients of the central environmental protection inspection on the green economic efficiency of the city are −0.013, 0.025 and −0.004, respectively, which indicates that the central environmental protection inspection shows a more significant positive relationship with the green economic efficiency of the city. This is consistent with the findings of Li Feng et al. (2022) [38] that the 'Central Inspections of Environmental Protection improve environmental quality and reduce wastewater discharge'. However, the green institutional arrangement has a negative impact on the green economic efficiency of the city both before and after the central environmental protection inspection, and the time of the central environmental protection inspection. The closer the time to the Central Inspections of Environmental Protection, the greater the negative impact on the green economic efficiency. The Central Inspections of Environmental Protection focus on monitoring environmental protection under the local government–enterprise interaction, and, by collecting clues from society, they identify and deal with outstanding environmental problems in a timely manner, which creates some institutional incentives for environmentally friendly enterprises and has a supportive effect on the urban green economic efficiency in general. As the Central Inspections of Environmental Protection cover matters such as the party and government's responsibility for ecological protection and the promotion of the implementation of double responsibility for ecological protection, in response to the environmental protection inspections, local governments set out to rectify environmental pollution problems before the inspections, and in order to quickly achieve the desired results, a "one-size-fits-all" approach is inevitable at the implementation level, which has an impact on the normal market economic order and even reduces the green economic efficiency. This can have an impact on the normal market economy and even reduce the efficiency of the green economy. In addition, the Central Inspections of Environmental Protection have urged local governments to continue to address environmental problems, which, on the one hand, reflects the importance of 'ecological priority', but, on the other hand, can lead to market uncertainty about 'green development'. On the one hand, this reflects the importance of 'ecological priority', but, on the other hand, it can lead to a market that is hesitant about 'green development', potentially reducing the efficiency of cities' green economies.

4.2. Central Inspections of Environmental Protection and Green Economy Efficiency: Locational Impact Variability

Considering the spatial distribution and historical tradition of industrial development in China since the reform and opening up of the country, cities in different geographical locations will, to some extent, influence the effect of the Central Inspections of Environmental Protection on the efficiency of the urban green economy. For example, in the late Qing Dynasty and early Republican period, Chongqing, Wuhan, Nanjing, Shanghai and Anqing along the Yangtze River were known as the 'Five Tigers of the Yangtze' and played an important role in the modern history of China. In fact, coastal riverside regions have a more export-oriented economy than non-coastal riverside regions, and, with capital accumulation and international benchmarking of the market development environment, the economic structure has been gradually transformed and optimized and may appear more positive and optimistic in their response to the central environmental protection inspection system. Therefore, the interaction term between whether coastal and riverine areas and the Central Inspections of Environmental Protection was introduced in the benchmark model to discuss the mechanism of the role of the Central Inspections of Environmental Protection on the urban green economic efficiency, and the estimated results are collated in Table 4.

Combining the Log-likelihood, AIC and SC value magnitudes, models (2) and (6) were selected for the next step of the analysis. The estimation results show that the interaction term (DID) regression coefficient, i.e., the treatment effect coefficient, is 0.027 for coastal riverine areas, which passes the 5% significance level test, while the treatment effect is insignificant for non-coastal riverine areas, indicating significant locational variability in the impact of the Central Inspections of Environmental Protection on the urban green economic efficiency. The economic explanation is as follows: for coastal cities such as Shanghai and Nantong and riverine cities such as Nanjing, Suzhou and Wuxi, the Central Inspections of Environmental Protection have an important role in raising the level of the green economic efficiency in cities; this is in line with Hong Tao et al.'s [39] study that "centralized environmental governance and strict legal regulations may provide strong constraints on local government deregulation of the environment". On the one hand, the environmental protection inspectors' rectification of polluting enterprises that have been strongly reflected by the public is conducive to eliminating "black" industries and reshaping the green industrial system to improve the efficiency of the city's green economy; on the other hand, the accountability, notification and treatment of possible corruption are conducive to optimizing the political ecology and building a new type of pro-clear government–business relationship. This will have a positive impact on the city's ability to move up the value chain, develop technology-intensive industries and enhance development efficiency.

Table 4. Central environmental inspections and green economy efficiency: variability in locational impacts.

	Coastal and Riverine Areas			Non-Coastal Riverine Areas		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Model type	OLS	SLM	SEM	OLS	SLM	SEM
Interaction Item (DID) × Zone	0.021 (1.4)	0.027 ** (2.086)	0.013 (1.118)	−0.006 (−0.291)	−0.004 (−0.227)	0.006 (0.342)
Control variables	Control	Control	Control	Control	Control	Control
R-squared	0.21	0.273	0.252	0.162	0.194	0.264
Log-likelihood	89.525	91.213	90.115	88.323	89.128	89.714
AIC	−159.05	−160.426	−160.23	−156.647	−156.256	−159.428
SC	−141.914	−141.577	−143.094	−139.511	−137.406	−142.293

Note: ** denote 5% significance levels; t/z values in parentheses. Regression results for control variables are omitted for space constraints and are available from the authors upon request.

4.3. Central Inspections of Environmental Protection and Green Economy Efficiency: Geographical Impact Variability

In order to more comprehensively reflect the impact of the Central Inspections of Environmental Protection on the efficiency of urban green economies, it is important to take full account not only of the variability in the location of particular cities, but also to discuss the heterogeneity of particular regions with different development histories. In Jiangsu province, for example, the southern region of Jiangsu, with Nanjing, Suzhou, Wuxi, Changzhou and Zhenjiang as representative cities, the central region of Jiangsu, with Yangzhou, Taizhou and Nantong as representative cities, and the northern region of Jiangsu, with Xuzhou, Lianyungang, Suqian, Huaian and Yancheng as representative cities, show a decreasing spatial distribution pattern in terms of the degree of economic development, the proportion of green industries in the economic structure and the sensitivity to environmental regulation. There are also differences in the share of green industries in the economic structure and their sensitivity to environmental regulation. Therefore, the interaction term × geographical characteristics was introduced into the baseline model, and the results are reported in Table 5. Models (2), (6), (9) and (12) were selected for the next stage of analysis by combining the magnitudes of the Log-likelihood, AIC and SC values, respectively.

Table 5. Conduction path verification results.

Type	Southern Sudan			Su-Central Region			Northern Jiangsu Province			Shanghai Area		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	SLM	SEM	OLS	SLM	SEM	OLS	SLM	SEM	OLS	SLM	SEM
Interaction item (DID) × Geographical area	0.02 (0.856)	0.029 ** (1.401)	0.017 (0.899)	0.008 (0.38)	0.012 (0.656)	−0.002 (−0.108)	0.008 (0.396)	0.01 (0.583)	0.016 (1.124)	0.002 (0.345)	−0.002 (−0.038)	−0.058 ** (−1.503)
Control variables	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
R^2	0.179	0.231	0.263	0.163	0.202	0.26	0.164	0.2	0.291	0.16	0.194	0.323
Log-Likelihood	88.746	90.065	90.04	88.363	89.317	89.667	88.371	89.271	90.242	88.268	89.103	90.468
AIC	−157.492	−158.13	−160.081	−156.725	−156.635	−159.332	−156.741	−156.542	−160.485	−156.536	−156.206	−160.937
SC	−140.356	−139.28	−142.945	−139.59	−137.785	−142.196	−139.606	−137.693	−143.349	−139.401	−137.357	−143.801

Note: ** denote 5% significance levels, respectively; t/z values in parentheses. Regression results for control variables are omitted for space constraints and are available from the authors upon request.

The results show that the regression coefficients of the interaction term × geographical characteristics, i.e., the treatment effect coefficients, pass the significance test (coefficients of 0.029 and −0.058, respectively) for the southern and Shanghai regions; while the central and northern regions of Suzhou do not show significant results, the findings are consistent with those of Y Tan et al. [40] regarding the impact of the Central Inspections of Environmental Protection on the air quality in China. In fact, compared to the central and northern regions, the southern region of Suzhou is at a higher level of economic and social development due to its good location and historical tradition of opening ports and trading in the late Qing and early Ming dynasties, and its economic structure is dominated by collective enterprises and foreign-funded enterprises, which tend to be stronger and have the ability and willingness to install pollution control equipment through research and development or the purchase of green innovative technologies under the central environmental protection inspection system arrangement, and to respond to the government's This micro-level green decision making drives the efficiency of the city's green economy. For Shanghai, the economic development leader in the Yangtze River Delta region, despite positive results in the development of the new economy, the impact of the Central Inspections of Environmental Protection on traditional industries, of which COSCO Shipping, China Baowu Steel and China Electric Equipment are the backbone, remains high, with increased environmental protection expenditure crowding out productive capital expenditure to some extent and inhibiting corporate R&D, constraining the city's green economic efficiency.

Table 5 shows the central environmental inspections and green economy efficiency: variability in geographical impact.

4.4. Central Inspections of Environmental Protection and Green Economy Efficiency: Spillover Impact Variability

Given the spatial spillover, it is necessary to take into account the impact of the Central Inspections of Environmental Protection on the green economic efficiency of non-inspected areas when discussing the effect of the Central Inspections of Environmental Protection on the green economic efficiency of cities. In fact, the integrated development of the Yangtze River Delta was proposed in 2010, and, in 2018, the central government supported the integrated development of the Yangtze River Delta region and elevated it to a national strategy, promoting a large number of major infrastructure developments and a series of institutional policy synergies through the release of a phased development plan outline, with an increasingly rational interaction between the three provinces and one city's industrial division of labor. Therefore, the interaction term × other regional characteristics was introduced into the benchmark model and the results are reported in Table 6. Combining the magnitude of the Log-likelihood, AIC and SC values, models (2), (5) and (9) were selected for the next stage of analysis, respectively.

Table 6. Central environmental inspections and green economy efficiency: spillover impact variability.

	Non-Inspector Areas			**Zhejiang Province**			**Anhui Province**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
	OLS	**SLM**	**SEM**	**OLS**	**SLM**	**SEM**	**OLS**	**SLM**	**SEM**
Interaction item (DID) × Other area	−0.017 (−1.138)	−0.025 ** (−1.878)	−0.012 (−1.092)	−0.01 (−0.784)	−0.014 * (−1.246)	−0.005 (−0.524)	−0.012 (−0.422)	−0.016 (−0.657)	−0.018 * (−0.865)
Control variables	Control	Control	Control	Control	Control	Control	Control	Control	Control
R-squared	0.193	0.259	0.264	0.176	0.224	0.254	0.164	0.202	0.279
Log-likelihood	89.106	90.822	90.2	88.67	89.875	89.78	88.385	89.317	90.013
AIC	−158.212	−159.645	−160.4	−157.34	−157.75	−159.559	−156.77	−156.633	−160.026
SC	−141.076	−140.796	−143.264	−140.204	−138.901	−142.423	−139.634	−137.784	−142.891

Note: **, * denote 5%, 10% significance levels, respectively; t/z values in parentheses. Regression results for control variables are omitted for space constraints and are available from the authors upon request.

The results show that the regression coefficient of the Central Inspections of Environmental Protection interaction term × non-inspected region characteristics, i.e., the treatment effect coefficient, is −0.025, and the regression coefficients of the Central Inspections of Environmental Protection interaction term on Zhejiang and Anhui, i.e., the treatment effect coefficients, are −0.014 and −0.018, respectively, indicating that the Central Inspections of Environmental Protection had a negative impact on the green economic efficiency of the non-inspected regions, and the degree of impact on Anhui is higher than that on Zhejiang. In fact, the Central Inspections of Environmental Protection will have an impact on the green development status of the inspected areas for a certain period of time, and some enterprises choose to relocate their production across locations to other regions in order to avoid environmental regulations. H Wang et al. [41] even measured that the number of polluting enterprises shrank by 48% after the implementation of the Central Inspections of Environmental Protection. This is the reason why the green economy efficiency of cities in neighboring provinces such as Zhejiang and Anhui decreased after Shanghai and Jiangsu were inspected by the Central Environmental Protection Inspectorate, and it also confirms the existence of the "pollution refuge" phenomenon in the Yangtze River Delta region [42]. The transfer of industries from Shanghai and Jiangsu to Zhejiang follows a specific stepped path, and the costs of both explicit land use and implicit green regulation are clearly higher than those in Anhui, making the transfer of a small proportion of industries to Zhejiang and most to Anhui the next best option. As the transfer of industries across provinces (cities) tends to be light green or even black enterprises with low technology intensity, the greater the number of incoming industries, the more significant the negative impact on the efficiency of the local urban green economy.

Using the Yangtze River Delta cities as a case study, this paper analyses the heterogeneous impact of the Central Inspections of Environmental Protection on the efficiency of the green economy, which has certain applications in the formulation and improvement of environmental policies in China, such as paying attention to the expected impact on the economy before and after the release of policies. In the process of policy implementation, it is necessary to take full account of the industrial structure factors of cities in different zones and adopt differentiated initiatives, as well as to consider the dynamic distribution of economic activities within and outside the region and adopt cross-regional policy synergies. The limitation of this paper is mainly the sample size issue. The article's research targets 41 cities in the Yangtze River Delta region and is concentrated in eastern China, which may not allow for a comprehensive analysis of the impact of the Central Inspections of Environmental Protection on the efficiency of China's green economy. To overcome the limitations of the study, a more comprehensive and detailed assessment and analysis for cities in eastern, central and western China could be considered in the next step.

5. Conclusions and Insights

The existing literature on the effects of the Central Inspections of Environmental Protection focuses on the provincial level and lacks variation at the prefecture level. This article uses the first round of the Central Inspections of Environmental Protection and "look-back" in prefecture-level and above cities in the Yangtze River Delta region as a quasi-natural experiment to establish more reasonable green economic efficiency indicators based on OH (2010), taking prefecture-level and above cities in the Yangtze River Delta as research samples and combining the spatial heterogeneity characteristics in the process of policy implementation [43], and empirically investigates the impact of the Central Inspections of Environmental Protection on the urban green economic efficiency using a multi-period spatial DID approach, and further discusses the heterogeneity of the impact in the time before and after the inspections, in different zones and regions of the inspected areas, and in the non-inspected areas.

This study found that: (1) The Central Inspections of Environmental Protection collect opinions from society and weigh them against each other, both to deter black enterprises to a certain extent and to create institutional incentives for green enterprises, which in turn support the efficiency of urban green economies. In response to the Central Inspections of Environmental Protection's "look-back", local governments often adopt "one-size-fits-all" measures such as simple shutdowns and rectification in the process of environmental remediation in order to quickly achieve the desired results, which may affect the normal economic order and reduce the green economic efficiency. (2) In terms of regional differences, the Central Inspections of Environmental Protection have a significant positive impact on coastal and riverine areas, but not on non-coastal and riverine areas. Compared with non-coastal riverine areas, coastal riverine areas have a higher proportion of export-oriented industries, a more complete green industry system and stronger industrial agglomeration capacity [44], and are more optimistic and confident in responding to the Central Inspections of Environmental Protection, which have a positive effect on localities' efforts to build a new type of pro-clear government–business relationship, promote enterprises' commitment to green technology research and application and improve the urban green economic efficiency. The central environmental inspections have had a positive effect on the development of a new type of pro-business relationship, the promotion of enterprises' commitment to green technology research and development and the improvement of the city's green economic efficiency. (3) In terms of geographical variability, the Central Inspections of Environmental Protection had a positive and negative impact on the green economic efficiency in southern Jiangsu and Shanghai, respectively, but not in central and northern Jiangsu. Due to its good location and historical tradition of opening ports and trading in the late Qing and early Ming dynasties, the southern Jiangsu region is dominated by collective and foreign-invested economies, and under the constraint of the Central Inspections of Environmental Protection, it has developed and purchased green innovative technologies to install pollution control equipment through technological innovation [45], which has promoted the green transformation of enterprises and improved the efficiency of the city's green economy at the same time. (4) In terms of spatial spillover differences, the Central Inspections of Environmental Protection had a negative impact on the green economic efficiency of non-inspected regions, with a higher degree of impact in Anhui than in Zhejiang. In order to reduce the cost of pollution control under strict environmental regulations, some enterprises choose to relocate their production across locations to non-inspected areas. This cross-regional allocation of productivity [46] has a negative impact on the efficiency of the green economy in the cities they move to. Compared to Zhejiang, Anhui, a member of the Yangtze River Delta, has a cost advantage in absorbing low green technology value-added enterprises, but the green economic efficiency is also more negatively affected by the spillover effects of the Central Inspections of Environmental Protection.

This study reveals that, firstly, the Central Inspections of Environmental Protection can not only promote the government, market and society to reach a consensus on "ecological priority and green development", but also become an important institutional arrangement affecting the high-quality development of the urban economy by enhancing the efficiency of the green economy, which provides a new way of understanding "promoting the harmonious coexistence of human beings and nature". This provides a better understanding of the factors influencing the efficiency of the green economy [47] and to address the current challenges of multiple governance under environmental regulation in China. Secondly, improving the design of environmental regulations accompanying the Central Environmental Protection Inspectorate, properly handling the relationship between the inspections and development for different time cut-off points, reasonably regulating the use of administrative resources, and reducing inappropriate administrative intervention in the market allocation of resource factors is not only a basic requirement for integrated regional development, but also an important prerequisite for building a large national unified market and improving the efficiency of China's green economy. Once again, considering the existence of regional development path dependencies and the obvious differences in industrial institutions between regions at different stages of development [48], and the different degrees of influence of the Central Inspections of Environmental Protection on the green economic efficiency [49], it is important to study the implementation of differentiated environmental protection inspection policies based on regional heterogeneity characteristics to better achieve regional economic development goals. Finally, central environmental inspections should establish mechanisms for collecting information and clues on environmental issues across regions, urging rectification mechanisms and initiating accountability mechanisms, and strengthening inter-provincial coordination to achieve the parallel implementation of regional green policies as far as possible, which will not only help to reduce the distortion of the effectiveness of central environmental inspections by administrative fragmentation, but will also be beneficial in improving the overall green economic efficiency of the region and, thus, achieving a profound transformation of the Chinese economy.

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