Research article

# Accountability audit of natural resources and total factor productivity—Evidence based on Chinese listed companies

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A R T I C L E  I N F O

A B S T R A C T

Based on a natural event, namely a pilot accountability audit of natural resources conducted by local officials in 2014, this study empirically investigates the impact of the pilot on the total factor productivity (TFP) of enterprises. The study utilizes the Differences-in-Differences model with an observation window spanning from 2012 to 2015. The findings indicate a significant reduction in the total factor productivity of enterprises in the pilot area due to the implementation of the pilot program. The study identifies that this impact is primarily driven by increased production costs and decreased investment. Further analysis reveals heterogeneity in the effects, with regions characterized by low levels of economic development, distortions in the production element market, low competition in industries, heavy asset-intensive industries, large enterprises, and absolute holding enterprises experiencing a more pronounced impact of the audit on total factor productivity. Overall, this study sheds light on the influence of accountability audits of natural resources on the real economy and offers valuable insights for policymakers.

## 1. Introduction

For a long time, there has been a "promotion tournament" [1] where officials who perform well in terms of economic growth are granted more promotion opportunities. The economic development-focused evaluation system for officials has spurred local officials to drive the economy, resulting in rapid growth in China. However, local officials have neglected local environmental protection and ecological civilization. Consequently the substantial consumption of natural resources and pollution of the ecological environment have accompanied local economic development. This undermines the long-term sustainable development of China's economy.

Therefore, the government aims to rectify the current situation where local officials are excessively fixated on regional economic growth while neglecting ecological environment construction and natural resource protection. The government seeks to accomplish this through top-level design [2]. The government explicitly demands the inclusion of resource consumption, environmental damage, and ecological benefits in the evaluation system for economic and social development. Additionally, they aim to establish a target system, assessment methods, and reward and punishment mechanisms that align with the requirements of ecological civilization. Subsequently, the government proposes exploring the creation of a natural resource asset and liability statement, implementing an exit audit of natural resources during the tenure of leading cadres, and establishing a lifelong accountability system for ecological and environmental damage [3]. The implementation of exit accountability audits of natural resources for local officials' represents a significant change in the traditional appraisal system. This change prioritizes the protection of natural resources and the ecological

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environment alongside economic development. It provides local officials' with incentives to safeguard and enhance their natural resources and ecological environment.

Since the introduction of local officials' exit accountability audits of natural resources, numerous studies have emerged to explore and examine this concept in China. Existing literature primarily focuses on local officials' exit accountability audits of natural resources [4–6], audit objectives [7,8], framework construction, and indicator design, supporting systems [9], the preparation of natural resource balance sheets [10], and audit content and methods [11–13], among other topics.

Over the past two years, several articles have empirically studied the policy effects resulting from local officials' exit accountability audits of natural resources, and these studies primarily focus on the company, regional, and environmental governance levels.

These studies are important for understanding the relationship between exit accountability audits of natural resources conducted by local officials and corporate financial behavior, as well as environmental control. However, they do not consider the impact of these audits on the economic effects and the micro-level coping mechanisms of firms. In comparison to the macro level, micro enterprise data provides more information, making it convenient to examine enterprise micro behavior and address the issue of individual heterogeneity. Total Factor Productivity (TFP) represents the additional production efficiency achieved under the conditions of the established levels of various factor inputs, and is an efficiency indicator of the transformation of inputs into outputs and a common measurement tool of enterprise business results at the micro level, which is an important manifestation of the enterprise's business situation and production capacity. By studying the effect of exit accountability audits of natural resources conducted by local officials on the productivity of micro enterprises (TFP), a more accurate understanding of the policy effects can be obtained. This understanding can also serve as a reference for policymakers when formulating policies.

Therefore, this study aims to examines the relationship between exit accountability audits of natural resources conducted by local officials and the total factor productivity of enterprises, using data from the first pilot of these audits in 2014.

The introduction of exit accountability audits of natural resources during the tenure of local officials' encourages them to prioritize environmental management and protection, thereby strengthening regional environmental controls. Existing literature suggests that environmental regulation can have both negative and positive effects on firms' factor productivity through different channels. These include production costs, investment disincentives, inefficient firm elimination, and innovation promotion mechanisms. The production cost mechanism suggests that environmental regulations require firms to adopt higher-cost clean energy sources, investing pollution control equipment, and upgrade or revamp highly polluting production lines. Consequently, this increases production costs and reduces income productivity. The investment disincentive mechanism suggests that uncertainty about future environmental regulations creates uncertainty for firms, which can delay their investment decisions. This uncertainty affects the development of new products and production processes, leading to a decline in productivity [14]. The inefficient firm elimination mechanism suggests that environmental regulations eliminate highly polluting firms with low technological capabilities, thus increasing the average productivity of regional firms [15,16]. On the other hand, the innovation promotion mechanism posits that appropriate stringency in environmental regulation can enhance firm productivity by stimulating the development of new technologies or organizational methods. This idea is known as the Porter hypothesis [17].

Based on the above theories, this study hypothesizes that the strengthened environmental control resulting from exit accountability audits of natural resources conducted by local officials' will have an impact on the total factor productivity of enterprises in the pilot region. This impact could be positive, negative, or insignificant.

In this study, we use the DID model to test the aforementioned hypotheses. We select heavy-polluting and resource-based firms in the first pilot areas in 2014 as the experimental group, and heavy-polluting and resource-based firms in the non-pilot areas as the control group. We empirically study the changes in total factor productivity of the two groups of firms before and after the pilot years, using the observation window of 2012–2015. The final sample comprises 1992 observations, with 114 in the experimental group and 1878 were in the control group. As firms in pilot regions may systematically differ from those in non-pilot regions, we also utilized propensity score matching (PSM) for testing.

Preliminary regressions in this study reveal that local officials' exit accountability audits of natural resources significantly reduce firms' factor productivity. These findings hold true after conducting robustness tests, such as propensity score matching (PSM), the placebo test, and the use of alternative methods to estimate firms' factor productivity.

Next, this study investigates the channels through which the pilot of the local officials' exit accountability audits of natural resources reduces firms' productivity. It is found that, firms in the pilot areas experience an increase in production costs and a decrease in investment activities compared to the non-pilot areas.

Additionally, this study finds that the effect of local officials' exit accountability audits of natural resources on total factor productivity of firms in the pilot regions is more significant in areas characterized by low economic development, high factor market distortion, low competitive industries, asset-heavy industries, large firms, and firms under absolute control.

One limitation of this study is that the premise of this paper's analysis is that enterprise total factor productivity captures the impact of the initial round of the local officials' exit accountability audit of natural resources. This limitation restricts the analysis of this paper limited to short-term studies rather than long-term studies, which may affect the conclusions of this study to some extent. For example, the long-term impact of the pilot projects on enterprise innovation, which is a process that may not be reflected in the short term, may bring additional limitations. Another limitation of this study is the sample selection. The study focuses on listed companies in the pilot regions and does not consider the possibility of enterprise closures or exits during the testing period. Consequently, the study fails to observe the impact of the elimination mechanism on the total factor productivity of enterprises. However, previous studies have found that similar environmental regulatory policies have led to the exit of small firms in polluting industries that utilize inefficient production technologies [18,19], resulting in an increase in the average productivity of regional firms [15,16].

This paper contributes to the existing literature in several ways. Firstly, most of the existing studies on the local officials' exit

accountability audit of natural resources are normative in nature, focusing on the conceptual aspects [4–6], audit objectives [7,8], framework construction, indicator design, supporting system [9], the preparation of natural resource balance sheet [10], and audit content and methods [11–13], etc. While a few scholars have conducted firm-level studies on the policy effects of the local officials' exit accountability audit of natural resources, their focus has primarily been on corporate surplus management [2], equity financing costs [3,20], tax avoidance behavior [21], stock price volatility [22], green M&A [23], and green innovation [24,25]. The impact of the policy on total factor productivity of enterprises has not been studied. This study empirically investigates the impact of the pilot local officials' exit accountability audit of natural resources on the total factor productivity of enterprises at the microeconomy level, thus filling this research gap. Secondly, this study also contributes to the examination of the impact of environmental regulations. Existing literature suggests that environmental regulation affects total factor productivity of firms' through various channels. Some scholars argue that environmental regulation reduces productivity by increasing firms' production costs and delaying their investment decisions [14,26]. However, other studies find that environmental regulation eliminates highly polluting firms with lower levels of technological capabilities [15,16,18,19] and incentivizes firms to develop new technologies or organizational approaches [17], thereby increasing firm productivity. This study demonstrates that enhanced environmental controls resulting from the local officials' exit accountability audits of natural resources can have a negative impact on the total factor productivity of firms in pilot areas by increasing production costs and reducing firms' investment activities. Lastly, the findings of this study provide valuable insights for relevant policymakers. Given that the local officials' exit accountability audit of natural resources reduces total factor productivity, it is important for the government to consider adjusting the policy implementation approach of the audit to mitigate its impact on firms' TFP, particularly through the reduction of production costs and the promotion of investment channels.

## 2. Institutional background and hypothesis development

### 2.1. Institutional background

The primary instrument for evaluating local officials is the accountability audit, it involves conducting a comprehensive assessment of the financial situation and business results during a manager's term of office to enforce economic responsibility when they vacate their position. The accountability audit system for leading cadres in China originated in 1985. After 1995, relevant organizations recommended piloting existing economic responsibility audits for cadres nationwide, leading to the formal establishment of a system of exit audits for leading cadres in China. After years of effort, China has established a relatively robust system for the exit audits of leading cadres, which primarily focuses on major economic decisions, financial revenues and expenditures, government investments. The exit audit system for leading cadres serves as a crucial reference for the selection and evaluation of officials.

The assessment of officials based on economic performance has resulted in a "promotion tournament" in China [1]. Officials who demonstrate strong economic growth are granted more promotion opportunities. The official economic development-oriented appraisal system has incentivized local officials to vigorously drive economic growth, contributing to remarkable achievements in China's rapid economic development in recent decades. However, the economic development-oriented official appraisal system has led local officials to blindly pursue short-term rapid economic growth in their jurisdictions, neglecting the serious damage inflicted upon natural resources and the ecological environment. To safeguard the ecological environment and achieve sustainable economic development, the Party and the government aim to reverse the current trend of local officials blindly pursuing regional economic growth while neglecting ecological construction and natural resource protection [2]. Therefore, building upon the traditional exit audits for leading cadres', another attempt has been made to establish an exit audit for local officials concerning natural resources.

The local officials' exit accountability audit of natural resources refers to the examination conducted by auditing authorities to protect, manage, develop, and utilize natural resources assets. It encompasses financial income and expenditure activities related to natural resource assets [4]. The objective of the local officials' exit accountability audit of natural resources is to promote the comprehensive and effective implementation of responsibilities pertaining to natural resource protection [9]. The audit targets primarily include the leading cadres who bear responsibility for natural resource asset management, and the results of these audits are integrated into the assessment system for leading cadres, serving as a crucial basis for cadre assessment, appointment, dismissal, rewards, and punishments [5].

When the concept of the local officials' exit accountability audit of natural resources was initially proposed, a preliminary pilot strategy was adopted before broader promotion. Pilot studies have been conducted in several provinces throughout the country since 2014, and building upon the pilot study, specific requirements for this initiative were articulated by the government in November 2017, stipulating a transition from the pilot stage to the full implementation stage starting in 2018.

Since the introduction of the local officials' exit accountability audits of natural resources, numerous studies have been conducted in China to explore and examine the phenomenon. The existing literature primarily focuses on the concept of local officials' exit accountability audits of natural resources [4–6], audit objectives [7,8], framework construction and indicator design, supporting systems [9], the preparation of natural resource balance sheets [10], and audit content and methods [11–13], among others.

Over the past two years, several articles have gradually emerged that empirically examine the policy effects resulting from local officials' exit accountability audits of natural resources. These studies primarily focus on the company, regional, and environmental governance levels.

Regarding the content of firm-level studies, Liu [27] analyzed the implementation of local officials' exit accountability audits of natural resources in specific regions and found that these audits reduce corporate surplus management. Quan [3] demonstrated that these audits increase investors' expectations of uncertainty regarding the future operations of heavily polluting and resource-based firms, leading to higher risk premiums and greater equity financing costs. Jiang, and Fangcheng [21] discovered that the

implementation of the local officials' exit accountability audits of natural resources significantly curbs tax avoidance by companies in resource-based and heavily polluting industries, suggesting that the implementation of the local officials' exit accountability audit of natural resources will have a significant "monitoring" effect. He and Dan [22] revealed that these audits exacerbate stock price volatility in heavily polluting industries. Li and Liu [20] empirically demonstrated that the implementation of local officials' exit accountability audits of natural resources negatively affects corporate debt financing by increasing the cost of debt capital for the relevant companies. Some scholars have also found positive effects of these audits at the firm level, primarily in the promotion of corporate green M&A [23] and the improvement of the corporate green innovation level [24,25].

At the regional governance level, research has shown that local officials' exit accountability audits of natural resources can improve the environment and promote high-quality economic development [28]. Similarly, some scholars have noted the positive effects of implementing these audits on the development of the green economy [29], as well as rationalization and advancement of industrial structure within the manufacturing industry [30]. In addition, Zhang, Han and Huang [31–33] have suggested that the implementation of a local officials' exit accountability audits of natural resources also has a significant enhances environmental governance by local governments.

Lastly, in the field of environmental governance, Huang [34] empirically demonstrated that the implementation of this system can help rectify the chronic issues associated with the GDP-led promotion model in the long run, leading to continuous improvement in air quality through "progressive learning."

### 2.2. The exit audit of natural resources and total factor productivity

The traditional official appraisal system is primarily focused on economic development, leading local officials to prioritize regional GDP growth for the sake of promotion [1]. They allocate significant resources to economic construction, often neglecting the improvement of environmental quality within their jurisdictions. In some cases, they even adopt crude development models that harm the regional ecological environment, resulting in the deterioration of overall environmental conditions [32]. However, the introduction of local officials' exit accountability audits for natural resources represents a significant shift in the traditional appraisal system. This new approach emphasizes the protection of natural resources and the ecological environment alongside economic development. Consequently, destructive actions that harm resources and the environment not only affect political advancement but also hold officials accountable for life. This creates a strong incentive for local governments to safeguard and enhance natural resources by taking various environmental protection measures, for example, these may include increased supervision of relevant enterprises' environmental practices within their jurisdictions and stricter penalties for pollution.

The primary objective of local officials' exit-accountability audits of natural resources is to bolster ecological environmental protection by motivating officials to prioritize environmental management throughout their tenure [9]. Empirical studies have demonstrated a positive correlation between these audits and environmental governance. In pilot cities, there has been a significant increase in both financial investment in environmental protection and the level of environmental protection measures implemented by polluting enterprises, compared to non-pilot cities [32]. Therefore, this study asserts that local officials' exit-accountability audits of natural resources serve as a fundamental tool for environmental control.

Environmental control is an important factor that influences enterprises' TFP. Total factor productivity (TFP) is a commonly used measure that reflects the overall efficiency of enterprise inputs in producing final outputs [35]. The existing literature on the factors influencing TFP can be broadly divided into two categories: enterprise characteristics and the external environment. Research on the impact of environmental controls on TFP belongs to the latter category. Wang and Liu [27] showed that the change in total factor productivity of firms is affected by the degree of environmental regulation. When the intensity of environmental regulation exceeds what firms can afford, their total factor productivity decreases. Conversely, when the intensity of environmental regulation is weakened but sufficient to promote firms to conduct technological R&D, their total factor productivity rises. Moreover, when the intensity of environmental regulation is very low, the incentive to innovate in R&D is weak, resulting in a decrease in total factor productivity. Sheng and Zhang [36] examined the impact of "environmental control in two control zones" on firms' total factor productivity and found that the policy of two control zones hinders productivity growth by raising production costs on the one hand and raises the average productivity level in the zones by eliminating less efficient and highly polluting firms on the other hand. Minghua and Yongzhong [37] showed that, in the long run, a stronger degree of environmental control stimulates R&D investment, thus promoting regional technological innovation and increasing the firms' total factor productivity.

This study argues that the strengthening of regional environmental controls brought about by local officials' exit accountability audit of natural resources, will impact the total factor productivity of regional firms. This impact can be both negative and positive, affecting production costs, investment disincentives, inefficient firm elimination, and innovation promotion mechanisms. The production cost mechanism suggests that environmental regulation requires firms to adopt higher-cost clean energy, increase pollution control equipment, and upgrade or revamp highly polluting production lines. As a result, this leads to increased production costs and reduced income productivity [26]. The investment disincentive mechanism suggests that uncertainty about future environmental regulations increases the uncertainty faced by firms' investment decisions affecting the development of new products and production processes, ultimately leading to decreased productivity [14]. The inefficient firm elimination mechanism suggests that environmental regulation eliminates highly polluting firms with low technology levels [18,19], thus increasing the average productivity of regional firms [15,16]. The innovation promotion mechanism suggests that appropriately stringent environmental regulation can incentivize firms to develop new technologies or find new ways to increase productivity, aligning with the Porter hypothesis [17]. Porter's hypothesis posits that although environmental policies may initially increase costs, they can ultimately improve productivity and promote long-term economic growth. The "Porter hypothesis" has been tested in several empirical studies [38–42].

Combined with the analysis of the related literature above, we hypothesize that the enhanced environmental regulation resulting from the local officials' exit accountability audit of natural resources will have an impact on the TFP of enterprises in the pilot regions. Since the impact of environmental regulation on firms' factor productivity can be positive or negative, it may not be significant. Therefore, we propose the following three competing hypotheses: H1.1, H1.2, and H1.3.

**H1.1**.   Assuming all other factors remain constant, the pilot local officials' exit accountability audit of natural resources causes a decrease in the TFP of enterprises in the pilot area.

**H1.2**.   Assuming all other factors remain constant, the pilot local officials' exit accountability audit of natural resources leads to an increase in the TFP of enterprises in the pilot area.

**H1.3**.   Assuming all other factors remain constant, the pilot local officials' exit accountability audit of natural resources has no significant effect on the TFP of enterprises in the pilot area.

Based on previous related literature, this study hypothesizes that the pilot local officials' exit accountability audit of natural resources strengthens the level of environmental control in the pilot areas, politically connected enterprises can use their political resources to mitigate the negative effects of the pilot on their operations.

On the one hand, in terms of resource effects, enterprises with strong political connections can leverage their government contacts for advantages in information access. This enables them to timely and accurately understand system adjustments and policy trends better interpret leading cadres' natural resource asset release audits, proactively adjust their production and management strategies, and mitigate the risks brought about by system changes [3]. Furthermore, they continue to play an important role in resource acquisition [43]. Chen [7] finds that the political affiliation resulting from state-owned equity ensures the reputation of private enterprises at the institutional level. This affiliation helps private enterprises develop and obtain more economic resources and development space.

On the other hand, political connections also enable enterprises to avoid certain risks of regulations and punishments. It is foreseeable that after the implementation of the pilot project of the local officials' exit accountability audit of natural resources, the leading cadres in the pilot areas will strengthen investigation and punishments for environmental damage while simultaneously increasing the penalties for related enterprises. This change in assessment methods strengthens the motivation of leading cadres to protect the local environment. In an environment of heightened local environmental controls, firms with political connections can leverage their political resources to politically lobby for reduced environmental regulations or penalties compared to firms without political connections. Faccio [44] shows that an important purpose of introducing political connections in firms is to weaken the administrative regulations they face. Anderson [45] also found that penalties imposed on politically connected firms are less effective than those imposed on firms without political connections.

Therefore, we propose the following hypothesis: H2.

**H2**.   Assuming all other factors remain constant, enterprises with political affiliation can utilize the political resources at their disposal to reduce the negative impact of the pilot natural resource asset departure audit of leading cadres on enterprises.

Based on previous related literature, this study hypothesizes that the enhanced environmental controls resulting from local officials' exit accountability audits of natural resources will impact the total factor productivity of firms in pilot areas through several channels. Firstly, environmental controls require firms to adopt higher-cost clean energy, increase pollution control equipment, and upgrade or revamp highly polluting production lines. These actions increase production costs and reduce their revenue productivity [26]. Secondly, the uncertainty surrounding future environmental control policies will delay firms' investment decisions, which in turn affect the research and development of new products and production processes, resulting in lower productivity [14]. In addition, environmental regulations eliminate highly polluting SMEs with low technology levels and increase the average productivity of regional firms [18,19]. However, since this study focuses on listed companies as samples, and the data indicates that no sample firms were eliminated before or after the pilot, the elimination mechanism does not apply to this study. Finally, environmental regulation can improve productivity by encouraging firms to develop new technologies or organizational methods to enhance productivity [24, 25,17]. Combined with the above analysis, we propose the following hypotheses: H3.1, H3.2, and H3.3, to examine the impact mechanism of the local officials' exit accountability audit of natural resources on enterprise total factor productivity. Fig. 1 presents a logical diagram illustrating this impact.

**H3.1**.   Assuming all other factors remain constant, the pilot local officials' exit accountability audit of natural resources will increase the production costs of enterprises in the pilot area.

**H3.2**.   Assuming all other factors remain constant, the pilot local officials' exit accountability audit of natural resources leads to a
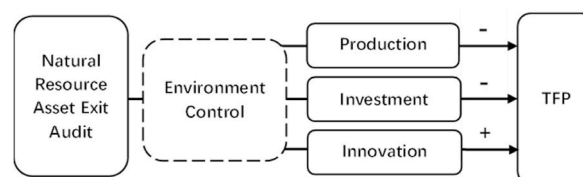


**Fig. 1.**  Research design logic diagram.

decrease in the investment activities of enterprises in the pilot area.

**H3.3.** Assuming all other factors remain constant, the pilot of the local officials' exit accountability audit of natural resources will lead to higher innovation inputs for enterprises in the pilot region.

## 3. Research design

### 3.1. Data and sample selection

In this study, we used resource-based and heavily polluting enterprises in the pilot areas as samples because they are the main sources of natural resource consumption and environmental pollution, which are directly related to the protection of natural resources and the improvement of the environment in the pilot areas. Therefore, they will be the key concern of local government leaders and cadres [2]. Similarly, enterprises with little or no impact on the environment do not receive much attention from local government leaders and cadres, and the strength of their environmental controls hardly affects their daily business activities. According to the "List of Listed Companies for Environmental Verification Industry Classification and Management" (Letter from the Ministry of Environmental Protection (2008) No. 373), "Guidelines for Disclosure of Environmental Information of Listed Companies" (Letter from the Ministry of Environmental Protection (2010) No. 78) and the "Guidelines for Classification of Listed Companies" revised by the China Securities Regulatory Commission in 2012, the heavy polluting, resource-based industries in this paper mainly include forestry, oil and gas extraction, mineral extraction, textile, paper, petrochemical, metal smelting, and electric power and heat production industries.

The exit accountability audits of natural resources by local officials were launched in 2014 in several provinces and cities across China. In this study, the resource-based and heavy-polluting enterprises in the first pilot areas in 2014 were selected as the experimental group, and the resource-based and heavy-polluting enterprises in the non-pilot areas were the control group. The DID model is used to empirically research the changes in TFP of the two groups before and after the pilot in the observation window of 2012–2015. By searching the websites of audit offices across the country, we obtained data from pilot regions for local officials' exit accountability audits of natural resources, specifically Shandong (Qingdao, Yantai), Hubei (Huanggang, Wuhan Jiangxia District), Inner Mongolia (Erdos, Chifeng), Hunan (Loudi), Guizhou (Chishui), Jiangsu (Lianyungang), Guangxi, Fujian (Fuzhou, Wuyishan), Shaanxi (Xi'an) and Sichuan (Mianyang). Other relevant data were obtained from the CSMAR database.

Among the samples of all A-share listed companies, after excluding non-heavy pollution, resource-based enterprises, and samples with missing data, we obtained 1992 observations for the final sample in this study, including 114 for the experimental group and 1878 for the control group. To exclude the effects of extreme values, all continuous variables are winsorized at the 1 % level.

### 3.2. Research design

#### 3.2.1. Model building

To test the true impact of the local officials' exit accountability audit of natural resources on firms' TFP, the model employs a differential approach to control for the moderating effect of political connections. The empirical model is shown in equation (1).

$$tfp_{i,t} = a_0 + a_1 * treat_{i,t} + a_2 * post_{i,t} + a_3 * treat_{i,t} * post_{i,t} + a_4 * pc_{i,t} + a_5 * treat_{i,t} * pc_{i,t} + a_6 * post_{i,t} * pc_{i,t} + a_7 * treat_{i,t} * post_{i,t} * pc_{i,t}$$
$$+ a_8 * state_{i,t} + a_9 * dual_{i,t} + a_{10} * big4_{i,t} + a_{11} * age_{i,t} + a_{12} * lev_{i,t} + a_{13} * capital_{i,t} + a_{14} * board_{i,t} + a_{15} * asset_{i,t} + a_{16} * gdp_{i,t} + \varepsilon_{i,t}$$
$$(1)$$

$$var_{i,t} = a_0 + a_1 * treat_{i,t} + a_2 * post_{i,t} + a_3 * treat_{i,t} * post_{i,t} + a_4 * pc_{i,t} + a_5 * treat_{i,t} * pc_{i,t} + a_6 * post_{i,t} * pc_{i,t} + a_7 * treat_{i,t} * post_{i,t} * pc_{i,t}$$
$$+ a_8 * state_{i,t} + a_9 * dual_{i,t} + a_{10} * big4_{i,t} + a_{11} * age_{i,t} + a_{12} * lev_{i,t} + a_{13} * capital_{i,t} + a_{14} * board_{i,t} + a_{15} * asset_{i,t} + a_{16} * gdp_{i,t}$$
$$+ year_{i,t} + ind_{i,t} + \varepsilon_{i,t}$$
$$(2)$$

In Model (1), TFP is the total factor productivity of the firm. For the pilot area sample, was set to 1; otherwise, it was set to 0. For the post-pilot (2014–2015) sample, the post was assigned a value of one; otherwise, it was assigned a value of zero. Treat*post is the core variable observed in this paper, if the coefficient of treat*post is significantly negative, it indicates that the pilot of the local officials' exit accountability audit of natural resources significantly reduces the TFP of enterprises in the pilot areas. If the coefficient of treat*post is significantly positive, it indicates that the pilot of the local officials' exit accountability audit of natural resources significantly improves the TFP of enterprises in the pilot areas. If the coefficient of treat*post is insignificant, it indicates that the pilot of the local officials' exit accountability audit of natural resources has no significant effect on the TFP of enterprises in the pilot areas. Pc is the political connections of enterprises; if enterprises have political connections, it equals 1; otherwise, it equals 0. Referring to existing studies [3], the political background of executives is used to determine whether the company has a political connection: if any of the executives is a former or current government official, deputy to the People's Congress, member of the Chinese People's Political Consultative Conference, among others. The dummy variable pc sets to 1; otherwise, it takes 0 based on existing literature [46,47]. This paper also controls for other variables such as the nature of the enterprise, dual office, whether the enterprise is audited by the "Big Four," age of the enterprise, gearing ratio, fixed assets ratio, board size, company size, and regional economic level. In addition, because this study is based on resource-based and heavy-polluting enterprises, and the dummy variable post is set in the time

dimension, Model (1) does not control for industry and year fixed effects to avoid multicollinearity among variables. However, when industry and year fixed effects are controlled for, the findings remain unchanged. Model (2) was developed to test the mechanism of the impact of the accountability audit of natural resources on enterprises' TFP. The variable var in Model (2) serves as a proxy variable for firm production cost, investment activity, innovation input, cost, and inv, r&d, respectively. Specifically, cost is calculated as the main operating cost divided by main operating revenue; inv is calculated as the construction and disposal of net cash from long-term assets divided by total assets at the end of the period; and r&d is calculated as the current r&d expenditure divided by main business revenue. Similar to Model (1), we treat*post as the observed core variable. The specific definitions of the variables are provided in Table 1.

### 3.2.2. TFP of enterprises

Firms' TFP is a common measure of the overall efficiency in transforming firm inputs into final output [35]. Its calculation is based on a logarithmic Cobb-Douglas production function. However, calculating TFP calculated using the standard OLS regression, taking residuals, may lead to biased estimates due to endogeneity issues. Therefore, scholars have improved their estimation methods, with the three most widely used being the OP, LP, and ACF.

The OP method was proposed and applied by Olley and Pakes [48] in 1996. Later, Levinsohn, and Petrin [49] proposed the LP method. The LP method uses firms' intermediate inputs as a proxy variable for unobservable productivity shocks, as the adjustment cost of intermediate inputs is small and all firms have intermediate input expenditures. The LP method can effectively solve the problem of missing samples generated by the OP method and can better reflect productivity changes [48].

However, Ackerberg [50] argued that both the OP and LP methods suffer from the "functional correlation" problem. Building on the OP and LP methods, Ackerberg [50] proposed a new method to solve the "functional correlation" problem, namely the ACF method, which overcomes the "functional correlation" problem and provides more accurate estimation results.

Therefore, we adopt the ACF and LP methods to estimate the TFP of enterprises. We use the main business revenue as the measure of output, the number of employees as the measure of labor input, fixed assets as the measure of capital input, and net cash from the construction and disposal of long-term assets as the measure of investment. In addition, we take the natural logarithm of the data.

Before taking the logarithm, we follow Lu [35] and deflate the corresponding indicators based on the chain of price index data provided in the China Statistical Yearbook. Specifically, we use 2009 as the base period (2009 price index = 100) and calculate the year-on-year price index for 2010–2015. We deflate the nominal output of enterprises by the ex-factory industrial producer price index to obtain the real output of enterprises. We deflate the nominal intermediate input by the industrial producer purchase price index to obtain the real intermediate input of enterprises, the nominal net fixed assets are deflated by the fixed asset investment price index to obtain the real net fixed assets of enterprises. Finally, we deflate the nominal net cash for the construction and disposal of long-term by the gross regional product index to obtain the real net cash for the construction and disposal of long-term assets of enterprises.

## 4. Analysis of empirical results

### 4.1. Descriptive statistics

Table 2 presents the descriptive statistics of the variables. The mean value of tfp_acf, calculated using the ACF method is 4.318 with a standard deviation of 0.350. Similarly, the mean value of tfp_lp calculated using the LP method, is 8.388 with a standard deviation of

**Table 1**
Variables and definitions.

| Variable | Variable description |
| --- | --- |
| *tfp_acf* | Total factor productivity of enterprises calculated with reference to the ACF method |
| *tfp_lp* | Total factor productivity of enterprises calculated with reference to the LP method |
| *tfp_liao* | Total factor productivity of enterprises calculated with reference to the Liao [36] method |
| *tfp_ols* | Total factor productivity of enterprises calculated with reference to the OLS method |
| *cost* | Enterprise production cost proxy variable, main operating cost divided by main operating revenue |
| *inv* | Proxy variable for corporate investing activities, construction and disposal of net cash from long-term assets divided by total assets at the end of the period |
| *r&d* | Proxy variable for enterprise innovation investment, current R&D expenditure divided by main business revenue |
| *treat* | Dummy variable, take 1 if the sample is the experimental group, otherwise take 0 |
| *post* | Dummy variable, take 1 if post-pilot (2014–2015) sample, otherwise take 0 |
| *pc* | Dummy variable, take 1 if the firm has political affiliation, otherwise take 0 |
| *state* | The nature of the enterprise, if the enterprise is a state-owned enterprise take 1, otherwise take 0 |
| *dual* | Two positions in one, the chairman of the board of directors and the general manager of the two positions together as soon as possible to take 1, otherwise take 0 |
| *big4* | If the company is audited by the "Big Four", take 1 if the company is audited by the "Big Four", otherwise take 0 |
| *age* | Age of business, current year minus year of opening |
| *lev* | Gearing ratio, total liabilities divided by total assets |
| *capital* | Fixed assets ratio, net fixed assets divided by total assets |
| *board* | Board size, natural logarithm of the number of board members |
| *asset* | Enterprise size, natural logarithm of total assets at the end of the period |
| *gdp* | Regional economic level, natural logarithm of GDP per capita in the province where the company is incorporated |

**Table 2**
Descriptive statistics.

| Variable | N | Mean | SD | Min | Max |
| --- | --- | --- | --- | --- | --- |
| tfp_acf | 1992 | 4.318 | 0.350 | 3.220 | 6.398 |
| tfp_lp | 1992 | 8.388 | 0.416 | 7.705 | 9.208 |
| tfp_liao | 1992 | 1.202 | 0.356 | 0.666 | 2.010 |
| tfp_ols | 1992 | 1.595 | 0.647 | 0.762 | 3.139 |
| cost | 1992 | 0.720 | 0.170 | 0.391 | 0.926 |
| inv | 1992 | 0.061 | 0.042 | 0.008 | 0.155 |
| r&d | 1992 | 0.003 | 0.007 | 0.000 | 0.025 |
| treat | 1992 | 0.057 | 0.232 | 0 | 1 |
| post | 1992 | 0.500 | 0.500 | 0 | 1 |
| pc | 1992 | 0.604 | 0.489 | 0 | 1 |
| state | 1992 | 0.436 | 0.496 | 0 | 1 |
| dual | 1992 | 0.218 | 0.413 | 0 | 1 |
| big4 | 1992 | 0.058 | 0.233 | 0 | 1 |
| age | 1992 | 16.482 | 4.573 | 5.000 | 37.000 |
| lev | 1992 | 0.414 | 0.199 | 0.094 | 0.752 |
| capital | 1992 | 0.378 | 0.175 | 0.121 | 0.737 |
| board | 1992 | 2.180 | 0.199 | 1.609 | 2.890 |
| asset | 1992 | 22.235 | 1.178 | 20.534 | 24.679 |
| gdp | 1992 | 10.895 | 0.386 | 10.268 | 11.513 |

0.416, which is consistent with previous results [51]. The mean value of the treatment variable is 0.057, and the mean value of post variable is 0.500. Since the data in this study are balanced panel data, it facilitates the calculation of firms' TFP. The results of the descriptive statistics of the other variables are similar to those of previous studies and will not be reiterated here.

To further demonstrate the trend of the TFP for resource-based and heavy-polluting enterprises in the pilot and non-pilot areas under the local officials' exit accountability audit of natural resources, Fig. 2 plots the mean productivity levels of enterprises calculated using the LP method from 2012 to 2015. As depicted in Fig. 2, the mean TFP of enterprises in the pilot areas was slightly higher than that of enterprises in the non-pilot areas in 2012 and 2013. However, the growth rate of mean TFP of enterprises in the pilot areas significantly slowed down after the commencement of the local officials' exit accountability audit of the natural resources pilot in 2014, and dropped significantly in 2015, reaching to a level significantly lower than that of the non-pilot areas. This finding implies that the audit pilot program had a negative impact on the TFP of enterprises within the pilot area to some extent.

### 4.2. Correlation analysis

Table 3 presents the correlation coefficient test matrix for the control variables chosen for this paper. The data indicate that there is no significant covariance among the selected control variables for this study.

### 4.3. Multiple regression analysis

Table 4 presents the results of the multiple regressions conducted for hypothesis testing. Columns (1) and (2) display the outcomes of the multiple regressions examining the relationship between local officials' exit accountability audits of natural resources and enterprises' TFP. The coefficients of the core observed variables treat*post in columns (1) and (2) are all significantly negative at a 1 % significance level. This indicates that the implementation of the pilot program for local officials' exit accountability audits of natural resources reduces the TFP of enterprises in the pilot areas, supporting hypothesis H1.1. However, hypotheses H1.2 and H1.3 are not supported.
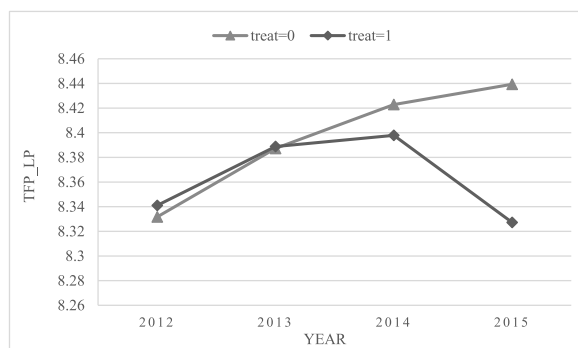


**Fig. 2.** Graph of changes in the mean level of enterprise productivity.

**Table 3**

Correlation analysis.

| Variable | pc | state | dual | big4 | age | lev | capital | board | asset | GDP |
|---|---|---|---|---|---|---|---|---|---|---|
| pc | 1 | | | | | | | | | |
| state | −0.021 | 1 | | | | | | | | |
| dual | 0.007 | −0.243*** | 1 | | | | | | | |
| big4 | 0.064*** | 0.151*** | −0.089*** | 1 | | | | | | |
| age | −0.109*** | 0.095*** | 0.023 | 0.012 | 1 | | | | | |
| lev | −0.015 | 0.381*** | −0.112*** | 0.074*** | 0.094*** | 1 | | | | |
| capital | 0.031 | 0.375*** | −0.159*** | 0.079*** | −0.021 | 0.460*** | 1 | | | |
| board | 0.037 | 0.318*** | −0.203*** | 0.107*** | −0.008 | 0.207*** | 0.219*** | 1 | | |
| asset | 0.049** | 0.424*** | −0.198*** | 0.339*** | 0.061*** | 0.563*** | 0.366*** | 0.376*** | 1 | |
| gdp | −0.097*** | −0.178*** | 0.090*** | 0.127*** | 0.082*** | −0.144*** | −0.071*** | −0.060*** | −0.052** | 1 |

**Table 4**

Hypothesis testing.

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | tfp_acf | tfp_lp | cost | inv | r&d |
| treat | 0.076 | −0.003 | −0.107*** | 0.015 | −0.001 |
| | (1.01) | (-0.04) | (-3.48) | (1.49) | (-0.30) |
| post | 0.011 | 0.011 | −0.009 | −0.025*** | 0.001 |
| | (0.52) | (0.48) | (-0.93) | (-7.89) | (1.24) |
| treat*post | −0.331*** | −0.314*** | 0.075* | −0.024* | −0.001 |
| | (-3.35) | (-2.96) | (1.89) | (-1.81) | (-0.26) |
| pc | 0.026 | 0.031 | 0.002 | 0.000 | −0.001 |
| | (1.34) | (1.51) | (0.25) | (0.05) | (-0.71) |
| treatpc | −0.061 | −0.016 | 0.119*** | −0.018 | 0.001 |
| | (-0.70) | (-0.17) | (3.36) | (-1.51) | (0.16) |
| postpc | −0.019 | −0.042 | −0.012 | −0.003 | 0.000 |
| | (-0.73) | (-1.47) | (-1.08) | (-0.97) | (0.45) |
| treat*postpc | 0.377*** | 0.358*** | −0.089* | 0.028* | −0.000 |
| | (3.22) | (2.84) | (-1.86) | (1.77) | (-0.04) |
| state | 0.041*** | 0.063*** | 0.048*** | −0.013*** | −0.001 |
| | (2.77) | (3.92) | (7.55) | (-6.05) | (-1.64) |
| dual | −0.011 | −0.044*** | −0.012* | 0.004* | −0.001 |
| | (-0.71) | (-2.63) | (-1.94) | (1.95) | (-1.41) |
| big4 | −0.045 | 0.041 | 0.001 | 0.012*** | −0.001 |
| | (-1.57) | (1.34) | (0.10) | (3.11) | (-0.87) |
| age | 0.005*** | 0.001 | −0.000 | −0.001*** | −0.000 |
| | (3.56) | (0.40) | (-0.49) | (-3.31) | (-0.95) |
| lev | −0.284*** | −0.087** | 0.232*** | −0.026*** | −0.002 |
| | (-6.95) | (-1.98) | (13.68) | (-4.64) | (-1.20) |
| capital | −0.479*** | −0.575*** | 0.088*** | 0.110*** | −0.003* |
| | (-11.57) | (-12.93) | (4.71) | (17.89) | (-1.73) |
| board | 0.051 | 0.008 | −0.015 | 0.002 | −0.000 |
| | (1.47) | (0.22) | (-1.03) | (0.34) | (-0.10) |
| asset | 0.061*** | 0.253*** | −0.022*** | 0.001 | −0.000 |
| | (8.33) | (31.86) | (-6.88) | (0.70) | (-1.53) |
| gdp | 0.083*** | 0.176*** | 0.015** | 0.001 | −0.000 |
| | (4.90) | (9.66) | (2.12) | (0.62) | (-0.39) |
| Constant | 2.089*** | 1.009*** | 1.106*** | 0.006 | 0.015 |
| | (8.78) | (3.93) | (9.63) | (0.16) | (1.41) |
| year | no | no | yes | yes | yes |
| Industry | no | no | yes | yes | yes |
| Observations | 1992 | 1992 | 1992 | 1992 | 1992 |
| R-squared | 0.148 | 0.501 | 0.586 | 0.251 | 0.135 |
| F | 21.49 | 124.0 | 81.63 | 19.31 | 8.964 |

Note: Values in square brackets under the regression coefficients are t-values, *, ** and *** indicate significant at the 10 %, 5 % and 1 % significance levels, respectively, as follows.

The coefficient of the variable treat*postpc is significantly negative at the 1 % level of significance, indicating that although the pilot accountability audit of natural resources strengthens the level of environmental control in the pilot area, firms with political affiliation can utilize their holdings of political resources to reduce the negative impacts of the pilot on the firms, and Hypothesis H2 holds.

Regarding for the control variables, the coefficient of state is significantly positive, suggesting that state-owned enterprises have higher TFP. On the other hand, the coefficient of dual is significantly negative, indicating that having two jobs simultaneously reduces

the TFP of enterprises; the coefficient of lev is significantly negative, implying that a higher debt ratio leads to lower TFP for enterprises. Moreover, the coefficient of capital is significantly negative, indicating that capital-intensive enterprises have lower TFP. Additionally, the coefficient of assets is significantly negative, indicating lower TFP for enterprises. Notably, the coefficient of capital is significantly negative, highlighting the lower TFP of capital-intensive enterprises. Conversely, the coefficient of assets is significantly positive, suggesting higher TFP for large enterprises. Furthermore, the coefficient of GDP is significantly positive, indicating that enterprises in more developed regions have higher TFP. The signs of the coefficients for all control variables align with expectations.

Considering that the sample enterprises in this study primarily consist of resource-based and heavy-pollution enterprises, and to prevent multicollinearity among variables, the regressions in columns (1) and (2) do not include controls for year and industry fixed effects. However, when controlling for the year and industry, the findings remain unchanged.

### 4.4. Impact mechanism research

Table 4 Columns (3), (4), and (5) show the results of multiple regressions analyzing the impact of the local officials' exit accountability audit of natural resources on the TFP of enterprises.

Column (3) presents the regression results for model (2) regarding the relationship between the local officials' exit accountability audit of natural resources and the production cost of enterprises. In column (3), the coefficient of the core observed variable treat*post is significantly positive, indicating that the pilot of the local officials' exit accountability audit of natural resources will increase the production cost of enterprises in the pilot areas, thus supporting hypothesis H3.1. Column (4) displays the results of the multiple regression analysis for model (2) examining the relationship between the local officials' exit accountability audit of natural resources and enterprise investment activities. In column (4), the coefficient of treat*post is significantly negative, which indicates that the pilot of the local officials' exit accountability audit of natural resources will lead to a decrease in the investment activities of enterprises in the pilot areas, supporting hypothesis H3.2. Column (5) presents the results of the multiple regression analysis for model (2) investigating the relationship between the local officials' exit accountability audit of natural resources and enterprises' innovation investment. In column (5), the coefficient of treat*post is not significant, indicating that the pilot of the local officials' exit accountability audit of natural resources has no significant effect on enterprise innovation investment in the pilot areas, thus hypothesis H3.3 does not hold.

In summary, the impact of the local officials' exit accountability audit of natural resources on the TFP of enterprises is mainly achieved by increasing the production costs and reducing investment activities. However, there is no significant impact on enterprise innovation resulting from the local officials' exit accountability audit of natural resources.

## 5. Robustness tests

### 5.1. Propensity score matching

To address the potential influence of omitted firm characteristics we utilize the Propensity Score Matching (PSM) method to match the experimental group samples one-to-one with a control group samples, aiming to maximize the similarity in terms of firm characteristics such as firm nature, firm size, gearing ratio, and regional marketability. Columns (1) and (2) of Table 5 display the results obtained from the PSM tests on firms' TFP, which were calculated using the ACP and LP methods based on the local officials' exit accountability audits of natural resources, respectively. The coefficients of treat*post are found to be significantly negative in both Columns (1) and (2). In comparison to the non-PSM sample, the significance of treat*post decreases in the regression results of the PSM sample, although it remains significant. Columns (3), (4), and (5) of Table 5 present the PSM sample tests for the impact mechanism. The regression results for the PSM sample align with those of the non-PSM sample, with the only difference being the change in significance levels. Consequently, the previous conclusions remain unaffected by firm characteristics or selectivity biases.

**Table 5**
PSM sample test.

| Variables | (1) | (2) | (3) | (4) | (5) |
| --- | --- | --- | --- | --- | --- |
| | tfp_acf | tfp_lp | cost | inv | r&d |
| treat | 0.021 | −0.044 | −0.126*** | 0.031** | −0.004 |
| | (0.21) | (-0.46) | (-2.92) | (2.33) | (-1.00) |
| post | −0.026 | −0.075 | −0.066 | −0.004 | 0.003 |
| | (-0.28) | (-0.86) | (-1.64) | (-0.34) | (0.71) |
| treat*post | −0.293** | −0.219* | 0.134** | −0.045*** | −0.001 |
| | (-2.13) | (-1.69) | (2.46) | (-2.61) | (-0.17) |
| controls | yes | yes | yes | yes | yes |
| year | no | no | yes | yes | yes |
| industry | no | no | yes | yes | yes |
| Observations | 220 | 220 | 220 | 220 | 220 |
| R-squared | 0.197 | 0.596 | 0.663 | 0.423 | 0.212 |
| F | 3.329 | 20.08 | 12.38 | 4.613 | 1.696 |

*5.2. Placebo test*

This eliminates potential omitted features between the pilot and non-pilot regions and further strengthens the robustness of the findings. Building on Quan [3], we conducted a placebo test and selected the observation window from 2010 to 2013, with 2012 serving as the dummy pilot period. The results of the empirical tests are presented in Table 6, which indicate that none of the coefficients of the core observed variables treat*post are significant. This suggests that the conclusions of this study are not influenced by the omitted regional characteristics.

*5.3. Other methods to estimate the explanatory variables*

In this study, Liao [52] and OLS methods were used to estimate the TFP of firms for the regression test in order to ensure the robustness of the results. The regression results obtained from the Liao and OLS methods, used to estimate the TFP of firms for the regressions presented in Table 7, are consistent with the findings of previous studies. This consistency indicates that the conclusions drawn are robust. In addition, different proxy variables were employed to test the impact mechanism study for the purpose of robustness testing. For instance, total operating cost/total operating income was used as a proxy for the cost of production of enterprises, net cash from construction and disposal of long-term assets/main operating income was used as a proxy for investment activities, and current R&D expenditure/main operating income was used as a proxy for innovation inputs. The test results confirmed the robustness of the aforementioned findings. Due to space limitations, the results of this test are not presented in this paper.

## 6. Heterogeneity analysis

In order to further investigate the factors that affect the impact of the local officials' exit accountability audit of natural resources on enterprise total factor productivity, we will explore the heterogeneity of this impact of the exit audit of natural resources on firms' TFP in three dimensions: regional characteristics, industry characteristics, and firm characteristics.

*6.1. Regional characteristics*

*6.1.1. Degree of regional economic development*

The degree of economic development is the most significant economic characteristic of these regions. Firstly, more economically developed regions have better market environments, more complete infrastructure facilities, more complete industrial chains, and more supporting industries. Secondly, the more developed the economy, the better the financial system, and the higher quality financial services that enterprises can obtain. Additionally, a more developed local economy means that local governments can provide a greater degree of support to the relevant industries. Based on the above analysis, we expect that more economically developed regions will have a weaker negative impact on TFP from the pilot, implying that the inhibitory effect of the local officials' exit accountability audit of natural resources on TFP decreases with an increase in economic development.

According to the size of GDP per capita in each region, the sample enterprises are divided into two groups: high and low economic development. Separate regressions are conducted for each group. The regression results are presented in Panel A of Table 8. Columns (1) and (2) show the regression results for the low economic development group, while Columns (3) and (4) show the regression results for the high economic development group. The coefficients of treat*post in columns (1) and (2) are both significantly negative at the 1 % level. In columns (3) and (4), only the coefficient of treat*post in column (3) is significant at the 10 % level. This indicates that an increase in economic development can mitigate the decrease in TFP caused by the pilot program, which is consistent with our expectations, and it may be due to the fact that more economically developed regions have better market environments, better financial systems, and stronger local government support.

**Table 6**
Placebo test.

| Variables | (1) | (2) | (3) | (4) | (5) |
| --- | --- | --- | --- | --- | --- |
| | tfp_acf | tfp_lp | cost | inv | r&d |
| treat | −0.125 | −0.109 | −0.049 | −0.005 | 0.001 |
| | (-1.39) | (-1.22) | (-1.39) | (-0.35) | (0.50) |
| post | −0.012 | 0.008 | 0.001 | −0.003 | 0.002*** |
| | (-0.49) | (0.35) | (0.07) | (-0.71) | (3.01) |
| treat*post | 0.180 | 0.151 | −0.058 | 0.020 | −0.001 |
| | (1.49) | (1.25) | (-1.22) | (1.07) | (-0.35) |
| controls | yes | yes | yes | yes | yes |
| year | no | no | yes | yes | yes |
| industry | no | no | yes | yes | yes |
| Observations | 1832 | 1832 | 1832 | 1832 | 1832 |
| R-squared | 0.173 | 0.153 | 0.560 | 0.221 | 0.125 |
| F | 25.35 | 21.85 | 69.46 | 15.43 | 7.79 |

**Table 7**
Other methods to estimate total factor productivity of firms.

| Variables | (1) | (2) |
|---|---|---|
| | tfp_liao | tfp_ols |
| treat | −0.032 | −0.056 |
| | (-0.33) | (-0.40) |
| post | 0.018 | −0.010 |
| | (0.68) | (-0.26) |
| treat*post | −0.323** | −0.333* |
| | (-2.58) | (-1.81) |
| controls | yes | yes |
| year | no | no |
| industry | no | no |
| Observations | 1992 | 1992 |
| R-squared | 0.0440 | 0.378 |
| F | 7.108 | 80.08 |

**Table 8**
Heterogeneity analysis.

| Variables | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | tfp_acf | tfp_lp | tfp_acf | tfp_lp |
| Panel:A | | *Low economic development group* | | *High economic development group* |
| treat*post | −0.373*** | −0.423*** | −0.262* | −0.219 |
| | (-2.76) | (-2.79) | (-1.80) | (-1.49) |
| R-squared | 0.135 | 0.480 | 0.171 | 0.537 |
| F | 10.18 | 60.36 | 13.49 | 75.70 |
| Panel:B | | *Low factor market distortion group* | | *High factor market distortion group* |
| treat*post | 0.011 | −0.085 | −0.357*** | −0.314*** |
| | (0.04) | (-0.26) | (-3.19) | (-2.62) |
| R-squared | 0.186 | 0.546 | 0.137 | 0.456 |
| F | 14.88 | 78.60 | 10.34 | 54.86 |
| Panel:C | | *High industry competition group* | | *Low industry competition group* |
| treat*post | −0.254* | −0.235* | −0.381*** | −0.373** |
| | (-1.85) | (-1.70) | (-2.73) | (-2.32) |
| R-squared | 0.221 | 0.431 | 0.114 | 0.533 |
| F | 18.52 | 49.46 | 8.392 | 74.54 |
| Panel:D | | *Light assets group* | | *Heavy assets group* |
| treat*post | −0.235 | −0.453* | −0.312*** | −0.291*** |
| | (-0.95) | (-1.68) | (-3.13) | (-2.72) |
| R-squared | 0.145 | 0.385 | 0.081 | 0.627 |
| F | 11.04 | 40.89 | 5.743 | 109.7 |
| Panel:E | | *Small business group* | | *Large business group* |
| treat*post | −0.218 | −0.082 | −0.329** | −0.273** |
| | (-1.32) | (-0.46) | (-2.56) | (-2.03) |
| R-squared | 0.174 | 0.251 | 0.149 | 0.459 |
| F | 13.73 | 21.89 | 11.41 | 55.34 |
| Panel:F | | *Non-Holding group* | | *Holding group* |
| treat*post | −0.292** | −0.238* | −0.414** | −0.450** |
| | (-2.55) | (-1.84) | (-2.05) | (-2.39) |
| R-squared | 0.181 | 0.430 | 0.111 | 0.598 |
| F | 22.92 | 78.20 | 3.380 | 40.01 |

*6.1.2. Degree of distortion in the factor market*

The higher the degree of distortion in the factor market, the stronger the local government's control over factor resources. Greater control over factor resources allows local governments to protect regional resources and the environment more effectively, which has a greater negative impact on local firms' TFP. Firstly, higher factor market distortions exacerbate factor resource mismatches and undermine the market's "survival of the fittest" elimination mechanism, resulting in lower productivity. Secondly, a higher degree of factor market distortion implies that local governments have greater pricing power and dominance over factor resources, making them more capable of increasing the protection of local resources, which will have a greater negative impact on the TFP of local enterprises. Therefore, we expect that the lower the degree of distortion in factor markets, the weaker the negative impact of the pilot of the local officials' exit accountability audit of natural resources on the TFP of enterprises. This means that the inhibitory effect of the pilot on firms' TFP decreases as the degree of factor market distortion decreases.

We draw on the approach of Zhang [51] to measure the degree of factor market distortion: Distort = (index of the product marketization process in each province and region–index of the factor marketization process)/index of the product marketization process. The relevant marketization index data for each province were obtained from Wang [53]. According to the degree of factor market

distortion in each region, the sample firms were divided into two groups – high and low – and regressed separately. The regression results are shown in Panel B of Table 8. Columns (1) and (2) show the regression results for the low-factor market distortion group, and columns (3) and (4) show the regression results for the high-factor market distortion group. The coefficients of treat*post in Columns (1) and (2) are insignificant, whereas the coefficients of treat*post in Columns (3) and (4) are significantly negative. This indicates that a reduction in factor market distortion can mitigate the reduction in TFP brought about by the pilot program, which is consistent with expectations, and it may be due to the fact that higher levels of factor market distortions, while bringing about low market productivity, also increase the level of protection of local resources and environmental regulation by local governments.

### 6.2. Industry characteristics

#### 6.2.1. Degree of competition in the industry

In more competitive industries, the screening mechanism of "elimination of the fittest" is more significant, and higher market pressure pushes enterprises in the industry to achieve higher productivity by reducing production costs and promoting technological innovation. Therefore, we expect that the impact of local officials' exit accountability audit of natural resources on reducing TFP through increasing production costs and decreasing enterprise investment is weaker in more competitive industries. This implies that the inhibitory effect of the local officials' exit accountability audit of natural resources on firms' TFP decreases as the degree of competition in the industry increases.

In this study, we use the Herfindahl Index (HHI) to measure the degree of competition in the industry. A higher HHI value indicates a lower degree of competition in the industry. The sample firms were divided into two groups based on the degree of competition in each industry – high and low – and were separately regressed. The regression results are presented in Table 8 Panel:C. Columns (1) and (2) display the regression results for the high industry competition degree group, while Columns (3) and (4) show the regression results for the low industry competition degree group. The coefficient of treat*post was significantly negative in all four regressions, indicating that the pilot program significantly reduced TFP overall, which aligns with the findings of the basic regression in this study. In addition, compared to the low industry competition group, the coefficients of treat*post are smaller, and the significance level of treat*post is lower in the high industry competition group. This suggests that an increase in industry competition can mitigate the reduction in TFP caused by the pilot of the local officials' exit accountability audit of natural resources. In other words, the inhibitory effect of the pilot program on firms' TFP decreases as the degree of industry competition increases, which is consistent with our expectations, and we suggest that this may be related to the fact that enterprises in industries with more competitive markets have greater incentives to improve productivity through channels such as reducing production costs and promoting innovation.

#### 6.2.2. Fixed assets ratio

The above findings suggest that the negative impact of exit accountability audits conducted by local officials on natural resources' TFP is mainly due to increased production costs and reduced investment. Firstly, the sample includes manufacturing industries with heavy assets, typically contribute to environmental pollution and are subject to stricter environmental regulations and penalties. Secondly, heavy-asset enterprises are often larger and have high fixed asset prices, making it challenging for them to upgrade their equipment and reduce pollution within a short timeframe. Heavy asset manufacturing industries generally experience low profit margins and low production efficiency. Based on the above analysis, we anticipate that the effect of local officials' exit accountability audits on natural resources will result in a stronger reduction of TFP in heavy asset industries, primarily through increased production costs and decreased enterprise investment.

According to the fixed assets ratio of each enterprise, the sample enterprises were divided into two groups–heavy and light assets–and regressed separately. The regression results are shown in Panel D of Table 8. Columns (1) and (2) show the regression results for the light asset group, and columns (3) and (4) show the regression results for the heavy asset group. In columns (1) and (2), only the coefficient of treat*post in column (2) is significantly negative at the 10 % level. In Columns (3) and (4), the coefficients of treat*post are both significantly negative at the 1 % level. This indicates that the TFP in asset-light industries was less negatively affected by the pilot, which is consistent with expectations, and we suggest that this may be related to some characteristics of firms with higher fixed asset ratios, such as higher environmental regulatory penalties, difficulty in upgrading equipment for environmental protection, and lower profitability.

### 6.3. Enterprise characteristics

#### 6.3.1. Enterprise size

First, enterprises with larger assets are usually large manufacturing enterprises, which usually pollute to a greater extent, and local governments can receive better environmental protection results by increasing the environmental supervision of these enterprises; thus, large enterprises are subject to more environmental regulation and punishment. Second, larger companies typically have more expensive fixed assets and more difficult equipment upgrades. In addition, large enterprises are well-known and will attract more public attention and social supervision. Therefore, we expect that the negative impact of local officials' exit accountability audits of natural resources on TFP is stronger in larger enterprises.

According to the total asset size of each enterprise, the sample enterprises were divided into two groups: large and small enterprises, and regressed separately. The regression results are presented in Table 8, Panel E. Columns (1) and (2) show the regression results for the small enterprise group, while columns (3) and (4) exhibit the regression results for the large enterprise group. The coefficients of treat*post in columns (1) and (2) are all insignificant, whereas the coefficients of treat*post in columns (3) and (4) are significantly

negative. This indicates that the TFP of large enterprises has a more pronounced negative effect on the pilot, aligning with expectations, and we argue that it is mainly due to the fact that larger firms are not only more difficult to upgrade their equipment and have a longer cycle, but are also subject to more government regulation and social supervision, and therefore the negative impact of the accountability audit of natural resources on the total factor productivity of firms is stronger.

### 6.3.2. Type of corporate holding

Enterprises with a shareholding of more than 50 % shareholdings by the largest shareholder are classified as controlling enterprises. Firstly, these enterprises are typically smaller, have a single production business, and exhibit weaker risk resistance to risks. Secondly, absolutely controlled enterprises are usually established within a short period with insufficient investment and low technical capabilities. In addition, absolutely controlled enterprises are often family-owned businesses with fewer political connections and are subject to stricter environmental regulations and penalties. Therefore, we anticipate that the negative impact of local officials' exit accountability audits on natural resources will be more pronounced in absolutely controlled enterprises, leading to a stronger effect on TFP.

Based on whether the shareholding ratio of the first-largest shareholder of the enterprise exceeds 50 %, the sample enterprises are divided into two groups: holding enterprises and non-holding enterprises. Separate regressions are conducted for each group. The regression results are presented in Table 8, Panel F. Columns (1) and (2) display the regression results for the non-controlling firm group, and columns (3) and (4) present the regression results for the controlling firm group. In all four regressions, the coefficients of treat*post are significantly negative, indicating that the pilot program significantly reduces TFP, which is consistent with the findings of this study. In addition, the coefficients of treat*post are larger for the holding enterprise group compared to the non-holding enterprise group, and the significance level of treat*post is higher. This suggests that holding enterprises have a greater negative impact on the TFP of the pilot program, aligning with our expectations, and we argue that this is mainly related to the characteristics of controlling enterprises, such as being less risk averse, having lower levels of investment and technology, and having fewer political connections and thus being more susceptible to more environmental regulations and penalties.

## 7. Conclusions and limitations

This study utilizes the initial pilot batch of the local officials' exit accountability audit of natural resources in 2014 to examine the influence of the audit on the total factor productivity of enterprises in the pilot areas. The empirical results indicate that the audit reduces the total factor productivity of enterprises. The study on the impact mechanism reveals that the audit affects the total factor productivity of enterprises in the pilot region primarily through two channels: increased production costs and decreased investment activities. In addition, this paper finds that the increase in firm innovation from a pilot accountability audit of natural resources is not significant. The analysis of heterogeneity reveals that the impact of the audit on the total factor productivity of enterprises in the pilot regions is more pronounced in areas characterized by low economic development, high factor market distortion, low competitiveness in industries, asset-heavy industries, large enterprises, and state-controlled enterprises. This study demonstrates that the local officials' exit accountability audit of natural resources enhances regional environmental control, consequently diminishing the productivity of regional enterprises. The findings of this study shed light on the influence of the audit on the real economy and provide a basis for policymakers in formulating policies.

However, it is important to note that the relatively short period since the initiaition of the local officials' exit accountability audit of natural resources started in 2014 imposes limitations on the findings of this study. For instance, the impact of the pilot program on enterprise innovation, which might be a long-term process, may not be immediately apparent. Additionally, because the sample selected for this study consists of listed companies and no enterprise closures or exits occurred during the testing period, it is impossible to ascertain the impact of the elimination mechanism on the total factor productivity of enterprises. In 2018, the local officials' exit accountability audit of natural resources was officially implemented nationwide. Therefore, we will continue to monitor the local officials' exit accountability audit of natural resources and its specific impact on the companies involved, considering its unique characteristics in China.

## CRediT authorship contribution statement

**Xin-jian Huang:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition. **Si-dai Li:** Writing – original draft, Visualization, Validation, Supervision, Software, Formal analysis, Data curation.

## Declaration of competing interest

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.

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