The Impact of Government Environmental Accountability on Green Total Factor Productivity Growth: from the Perspective of China's Experiment

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Abstract. Environmental protection and economic development are essential issues for achieving high-quality and sustainable economic development. This work focuses on this "natural experiment" conditions provided by China's phased and regional implementation of government environment responsibility regulation pilot policy, and uses the Difference-in-Differences (DID) method to analyze the panel data of 30 provinces in China from 2006 to 2019 to explore the causal relationship between government environmental regulation and Green Total Factor Productivity (GTFP). The results show that the implementation of government environment accountability regulation pilot policy has a significant effect on GTFP improvement, where technological improvements play an essential mediating role. In addition, the heterogeneity of economic development levels and the age of local officials also considerably affect the effectiveness of government environmental regulation. The effectiveness of government environment accountability regulation pilot policy was found to be stronger in economically underdeveloped areas or those with older local officials.

Keywords: government regulation; environmental management; local officials; green total factor productivity; difference in differences method

1 Introduction

Since the reform and opening-up, China has focused on economic development to enhance people's living standards and national strength, achieving impressive accomplishments (Shi et al., 2020).[1] Today, China, as the largest emerging and second largest economy globally, holds a crucial position in the world economy (Freeman, 2022).[2] China's remarkable economic growth has been followed by significant environmental damage and resource degradation (Xia and Xu, 2020a).[3] China contributed 30.64% of global carbon dioxide emissions from fossil fuels in 2020, making it the largest emitter globally. Its future carbon emissions trajectory is crucial for global mitigation plans. (Wang and Zhang, 2014).[4].

In recent years, to achieve a green and low-carbon transition, China has implemented strong policies, such as environmental accountability for officials, aiming to build a sustainable society. The pilot policy of government environmental accountability focuses on the outgoing audit of natural resource asset of local officials (OANRA). Officials who leave their positions

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will undergo an audit on the departure of natural resources and assets, including air and water environment protection. China piloted the OANRA policy in 15 cities in 2014, expanded the pilot program from 2015 to 2017, and implemented it nationwide from 2018.

Most existing studies measure the sustainable capacity of an economy in the following two ways. The first is Green GDP (Nordhaus, 1972).[5] However, the application of green GDP is flawed in that it is difficult to put a price on damage to the environment and natural resources due to the lack of property rights definition of the environment and natural resources (Xia and Xu, 2020a).[3] The second is the Green TFP (GTFP) index, which is an important indicator that combines economic growth with environmental protection to measure the quality of economic development, and improving GTFP is an essential way for the Chinese economy to achieve green development (Xia and Xu, 2020a).[3]

Based on the above considerations, this study focuses on the "natural experiment"conditions provided by China's phased and regional implementation of government environmental accountability, and uses the Difference-in-Differences (DID) method to analyze panel data from 30 Chinese provinces from 2006 to 2019 to investigate the causal effect between government environmental accountability and GTFP. It is found that there is a close promoted relationship between the pilot policy of government environmental accountability and the GTFP in Chinese provinces, where technological improvements play an essential mediating role. In addition, the heterogeneity of economic development levels and the age of local officials also affect the effectiveness of government environmental accountability to a large extent. The effectiveness of the pilot policy of government environmental accountability was found to be stronger in economically underdeveloped areas or those with older local officials.

2 Literature review

2.1 The measurement of GTFP

Traditional TFP estimation methods were focused on economic indexes like GDP, ignoring undesirable outputs, leading to distorted social welfare and economic performance evaluations. Pittman (1983) introduced DEA to consider undesirable output in GTFP estimation.[6] Chung et al. (1997) and Färe et al. (1989) expanded GTFP with a directional distance function and ML index, aligning with environmental concepts.[7][8] Xia and Xu (2020b) applied ML index based on DDF to measure GTFP in Chinese provinces (1997-2015), using bootstrapping to correct estimation bias and test significance.[3] The combination of non-parametric methods (e.g., DEA, DDF) and ML index is effective for GTFP evaluation.

2.2 The influencing factors of GTFP

Regarding GTFP influencing factors, previous studies focused on technological innovation and government policy. Some existing literature also studied the influence of government on GTFP from the perspectives of national reform policies, regulatory policies and financial policies:

(1) In terms of the national reform policies, Long et al. (2013) investigated the effects of environmental policy on environmental conditions resulting from China's accession to the

World Trade Organization (WTO).[9] Jiang et al. (2021) took Shanghai pilot free trade zone as an example to study the impact of the free trade zone on green total factor productivity.[10]

(2) In terms of the national regulatory policies, Wu et al. (2020) discussed the influence of environmental regulation and environmental decentralization on GTFP.[11] Cao et al. (2021) revealed that regulatory policy can impact two different types of GTFP at both the firm and industry levels.[12]

(3) In terms of the national financial policies, Hao et al. (2020) investigated the relationship between misallocation, corruption and GTFP by employing panel threshold model.[13] Xie et al. (2021) shown that financial agglomeration promotes the growth of urban GTFP, but significantly reduces the GTFP in the surrounding areas of the city.[14]

These studies discussed the influencing factors of GTFP extensively. However, none focused on the impact of OANRA policy on China's provincial GTFP, which is crucial for utilizing the outgoing audit system of natural resources to boost GTFP growth in China.

3 Methods

3.1 Empirical Model

To investigate whether OANRA policy has a GTFP improvement effect, the research refers to Cerulli (2015), takes the pilot policy as a quasi-natural experiment and adopts a difference in differences (DID) model as follows:[15]

$$\mathrm{GTFP}_{it} = \alpha_0 + \alpha_1 \mathrm{AUDIT}_{it} + \alpha_2 \mathrm{Controls}_{it} + \delta_i + \varepsilon_{it} \quad (1)$$

where GTFP_{it} is the variable green total factor productivity capturing capital, labor and energy factors of province i in year t; AUDIT_{it} denotes the dummy variable measuring the government accountability auditing pilot policy in year t and equals 1 if the province is the auditing pilot target; $\mathrm{Controls}_{it}$ denote other potential variables accounting for GTFP including environmental regulation, finance development, human capital, governmental governance level and level of opening; δ_i denotes the provincial individual effect and ε_{it} the error item. α_1 is the main coefficient of interest in this research, which implies the average treatment effect of auditing pilot on GTFP.

To examine the mechanism of how government accountability pilot policy (i.e., OANRA) affects GTFP, the panel mediating regression model is established:

$$\mathrm{GTFP}_{it} = \beta_0 + \beta_1 \mathrm{AUDIT}_{it} + \beta_2 \mathrm{Controls}_{it} + \delta_i + \varepsilon_{it} \quad (2)$$

$$\mathrm{M}_{it} = \gamma_0 + \gamma_1 \mathrm{AUDIT}_{it} + \gamma_2 \mathrm{Controls}_{it} + \delta_i + \varepsilon_{it} \quad (3)$$

$$\mathrm{GTFP}_{it} = \theta_0 + \theta_1 \mathrm{AUDIT}_{it} + \theta_2 \mathrm{M}_{it} + \theta_3 \mathrm{Controls}_{it} + \delta_i + \varepsilon_{it} \quad (4)$$

where M_{it} is the mediator variable and the meanings of other variables are consistent with the model (1).

3.2 Variable Construction

This paper uses Chen et al. (2018) non-parametric approach to measure GTFP, integrating resource and environmental constraints into the traditional TFP framework.[16] GTFP and technological change (TC) are calculated based on the SBM-DDF model, using 2004 as the base period. The four indicators are: (1) total electricity consumption for energy input; (2) number of employees for labor input, and capital stock (calculated using Zhang et al. (2004) method) for capital input; (3) GDP at constant price (deflated with 2004 as base) for expected output; and (4) discharge of "three industrial wastes" for undesirable output.[17]

For other potential determinants of GTFP, this paper investigates how environmental regulation, finance development, human capital, governmental governance level and level of opening may impact on the growth of GTFP. The economic-incentive environmental regulation (EIR) in this paper is measured by "growth rate of electricity consumption per unit of GDP (physical quantity)".

The second determinant is financial development (FD). The higher the level of financial development of a country, the more enterprises can rely on finance resource to leverage the productivity, the more likely it is that green total factor productivity will increase. "various deposits of financial institutions/regional GDP" is exploited to measure regional FD.

Human capital (HC) may account for GTFP to some extent. Labor factor or human capital initiates the subjectivity and inner power including the knowledge, skills and other techniques could affect how economic activities are organized and eventually the growth of GTFP. This paper measures HC with "number of students in colleges and universities / area population".

The institutional factors like governmental governance may influence China's GTFP growth. Therefore, this paper uses GG to investigate the effect of institutional factors and such indicator is measured by "regional public budget expenditure/regional GDP".

The last determinant is outward opening (OO). Opening to the outside world will bring foreign sophisticated technology and management advantages to drive the development of domestic productivity. This paper utilizes "total regional imports/regional GDP" to measure regional OO.

The mediation variable in this paper is innovation (INNO) measured by "the logarithm of the number of domestic three patent applications".

3.3 Data Source and Statistics Description

All data in this paper are available in China's national and provincial statistical yearbooks and environmental yearbooks. To match all data in which some may be missing in a certain year, the final data set obtained involves the panel data of 30 provinces from 2006 to 2019 in China. The statistics description is displayed in Table 1.

Table 1. Statistics Description.

Variable name	Mean	Standard Error	Minimum value	Maximum value
GTFP	1.514431	.5733218	.608019	4.97891
TC	1.510157	.4068456	.9042282	110.16967
AUDIT	.1428571	.3503444	0	1

EIR	-1.754732	4.56121	-15.89	18.36
FD	1.770383	.6768995	.8546264	5.188768
HC	.0182355	.0057484	.006004	.0378317
GG	.2417137	.109397	.0947823	.7583024
OO	14.32604	1.623993	9.693285	17.8218
INNO	8.936839	1.613124	4.369448	12.2852

4 Results

4.1 Benchmark Regression Results

Table 1 outputs the benchmark results of the impact of China's auditing targeted at outgoing leading officials' management of assets in the form of natural resources on green total factor productivity where the GTFP is the outcome variable. Column (1) corresponds to the regression without adding any control variables while column (2) is the regression of AUDIT on GTFP including the five control variables EIR, FD, HC, GG, OO. It can be seen that both column (1) and column (2) indicate the positive effect of auditing pilot policy (coefficient=0.581 and 0.154 respectively) at the 1% significant level, which implies that the pilot policy on the outgoing audit of natural resources assets for local officials in 2014 exerts significantly positive influence on China's green total factor productivity.

Table 1 Benchmark and Robustness Estimation Results.

	(1) GTFP	(2) GTFP	(3) TC	(4) LnGTFP	(5) GTFP
AUDIT	0.581***	0.154**	0.0892*	0.0765*	
	(0.0538)	(0.0735)	(0.0471)	(0.0384)	
AUDIT1					0.0891
					(0.0762)
EIR		0.0134***	0.0114***	0.00678***	0.0133***
		(0.00392)	(0.00258)	(0.00222)	(0.00392)
FD		0.605***	0.557***	0.320***	0.621***
		(0.178)	(0.142)	(0.0861)	(0.178)
HC		64.88***	47.47**	40.30***	66.80***
		(21.28)	(18.49)	(11.30)	(21.17)
GG		-0.680	-0.0389	-0.0368	-0.785
		(0.728)	(0.298)	(0.358)	(0.740)
OO		0.174**	0.108	0.144***	0.181**
		(0.0814)	(0.0676)	(0.0464)	(0.0832)
_cons	1.431***	-3.065***	-1.872**	-2.993***	-3.193***
	(0.00768)	(1.009)	(0.869)	(0.566)	(1.036)
N	420	420	420	420	420
R2	0.126	0.497	0.513	0.681	0.492

Considering control variables, FD, HC and OO all positively affect GTFP at the 1% significant level within expectations. The coefficient of EIR is also positive with 1% statistical

significance which is beyond expectation. The possible reason is that although the growth rate of energy consumption per unit of GDP (physical quantity) in China is increasing, it is still negative most of the time, which means that the pilot policy of government environmental accountability still has a positive effect on green development.

4.2 Robustness Test

To examine whether the benchmark estimation results are robust, three methods of robustness test are adopted in this section: (1) substituting the outcome variable GTFP with its decomposition term TC of GTFP and its logarithmic value LnGTFP; (2) moving the auditing pilot policy forward one year (2013) for a placebo test; (3) testing for parallel trends assumption of the DID model.

For robustness test 1, the results are displayed in column (3) and (4) of Table 1. The coefficients of AUDIT in column (3) and (4) are 0.0892 and 0.0765 respectively with 1% significant level and all control variables are also stable compared to the benchmark regression, suggesting strong robustness.

As for the placebo test (column (5) in Table 1), the coefficient of the new dummy policy variable AUDIT1 is not statistically significant. This means that when China's auditing pilot policy aiming at outgoing local officials' management of natural resources assets is moved forward by one year, the policy fails to promote GTFP, indirectly implying the robustness of benchmark estimation.

The parallel trends assumption is the precondition of DID model, so the robustness test 3 adopts the following model:

$$\mathrm{GTFP}_{it} = \omega_0 + \omega_{2007}\mathrm{AUDIT}_{2007} + \cdots + \omega_{2019}\mathrm{AUDIT}_{2019} + \omega_1\mathrm{Controls}_{it} + \delta_i + \varepsilon_{it} \quad (5)$$

where a set of dummy policy variables $\mathrm{AUDIT}_{2007}\sim$ are introduced to replace the key explanatory variable and the subscripts means whether province i is an audit pilot area in year t, the meanings of other variables are consistent with the model (1).

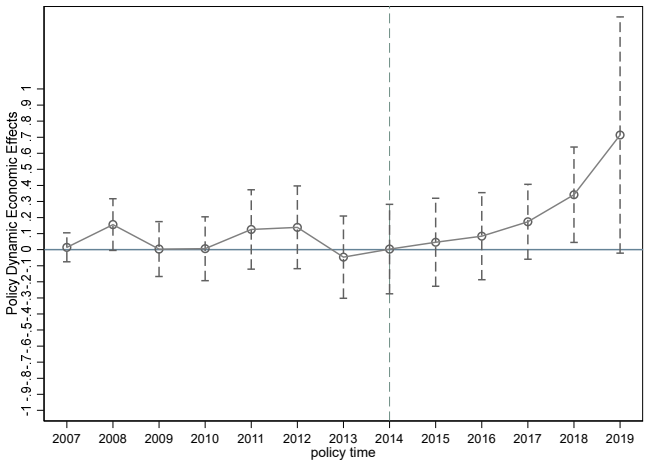

Figure 1. Parallel Trend Test.

Figure 1 provides the coefficients of all dummy policy variables and the corresponding 95% confidence interval. The chart shows that before the policy implementation time 2014, all coefficients (ω_{2007}~ω_{2013}) are not significantly different from 0, suggesting the parallel trends of the treatment and control group before 2014 is not significantly different from 0 while is significantly different from 0, indicating that there is a certain time lag in the impact of the 2014 audit pilot policy on green total factor productivity.

4.3 Regional Heterogeneity Analysis

Considering the potential influence of regional heterogeneity on the auditing pilot policy, the original sample is divided into two sub samples by geographic location and the East sample and the Midland and West sample are obtained. Table 2 shows the regional heterogeneity results and it can be found that the coefficient of AUDIT in column (3) (regression for Midland and West sample) is 0.210 larger than 0.154 in the benchmark regression with 1% significant level while that in column in column (2) (regression for East sample) is not significant, revealing that the auditing pilot policy effects are more significant in economically underdeveloped areas.

Table 2 Regional Heterogeneity Results.

	Benchmark	East	Midland and West
AUDIT	0.154**	0.116	0.210**
	(0.0735)	(0.141)	(0.0927)
EIR	0.0134***	0.0245*	0.0109***
	(0.00392)	(0.0120)	(0.00323)
FD	0.605***	0.671**	-0.197
	(0.178)	(0.222)	(0.258)
HC	64.88***	47.36	110.6***
	(21.28)	(41.00)	(16.13)
GG	-0.680	-0.725	0.722
	(0.728)	(2.343)	(0.841)
OO	0.174**	0.396**	-0.00513
	(0.0814)	(0.141)	(0.0608)
_cons	-3.065***	-6.886***	-0.242
	(1.009)	(2.086)	(0.731)
N	420	154	266
R2	0.497	0.361	0.733

4.4 Mechanism Analysis: The Mediation Effect of Technological Improvement

Technological improvement brings the evolution of traditional production and consumption modes towards energy conservation and emission reduction and eventually boosts GTFP. Therefore, to explore whether the auditing pilot policy affects GTFP through technological improvement, this section conducts mechanism analysis. Table 3 outputs the regression results of model (2)~(4) in column (1)~(3). The column (1) is the benchmark results, showing that auditing pilot policy can improve GTFP. The column (2) shows the regression of AUDIT on INNO and the coefficient of AUDIT is 0.432 ($p<0.01$), indicating that the auditing pilot policy can enhance technological improvement. The column (3) incorporates the AUDIT and INNO into the regression on GTFP and the coefficient of INNO is 0.190 with 5% significant level

while that of AUDIT is not significant, suggesting the complete mediation of technological improvement.

Table 3 Mechanism Analysis Results

	GTFP	INNO	GTFP
AUDIT	0.154**	0.432***	0.0722
	(0.0735)	(0.137)	(0.0797)
EIR	0.0134***	-0.00549	0.0145***
	(0.00392)	(0.00675)	(0.00363)
FD	0.605***	1.168***	0.383**
	(0.178)	(0.239)	(0.150)
HC	64.88***	128.3***	40.47
	(21.28)	(31.57)	(25.38)
GG	-0.680	2.251	-1.109
	(0.728)	(1.334)	(0.777)
OO	0.174**	0.520***	0.0749
	(0.0814)	(0.127)	(0.0543)
OO			0.190**
			(0.0761)
_cons	-3.065***	-3.533**	-2.393***
	(1.009)	(1.537)	(0.746)
N	420	420	420
R2	0.497	0.826	0.522

4.5 Further Analysis: The Age Characteristics of local officials

For local officials, older age means that they may take the initiative to promote the implementation of the auditing pilot policy due to greater pressure to avoid accountability for smooth transition to retirement, while younger local officials will not be troubled by this, but will still promote policy deployment because of promotion pressure. This paper selects the average age of mayors and municipal party secretaries of various cities in China in 2014 as the representative age of local officials in each province, and then calculates the average age of national local officials (52.2289) and uses this as a dividing standard to obtain two sub-samples: provinces whose representative age of local officials is older than 52.2289, plus the pilot provinces, are included in the older age sample, and provinces whose representative age of local officials is younger than this age plus the pilot province are included as the younger age sample. The results in Table 4 show that the coefficient of AUDIT of column (2) is larger (0.164, $p<0.01$) than that (both 0.154, $p<0.1$ and $p<0.05$) of column (1) and (3) which correspond to the results of benchmark and younger group regression, suggesting that accountability avoidance due to larger age of local local officials strengthens the effects of auditing pilot policy on green total factor productivity.

Table 4 Results of local officials' Age Division.

	Benchmark	Older Group	Younger Group
AUDIT	0.154**	0.164**	0.154*
	(0.0735)	(0.0767)	(0.0775)
EIR	0.0134***	0.0204***	0.00973***
	(0.00392)	(0.00678)	(0.00274)

FD	0.605***	0.539***	0.368
	(0.178)	(0.187)	(0.274)
HC	64.88***	48.64*	95.18***
	(21.28)	(26.20)	(18.94)
GG	-0.680	0.684	-0.766
	(0.728)	(1.480)	(1.092)
OO	0.174**	0.223**	0.0864
	(0.0814)	(0.0964)	(0.0748)
_cons	-3.065***	-3.774***	-1.783*
	(1.009)	(1.231)	(0.902)
N	420	252	308
R2	0.497	0.432	0.622

5 Conclusions

Our study confirms the significance of national environmental accountability policies for sustainable development. We observe a strong positive correlation between pilot environmental accountability policies implemented by provincial governments in China and GTFP, with technological progress serving as a key mediator. Furthermore, economic development level and the age of local officials significantly impact the effectiveness of these policies. Specifically, the policies are more effective in economically less developed regions and regions with older local officials.

The contribution of this study is reflected in the following three aspects: considering the potential impact of regional heterogeneity on the government's environmental accountability pilot policy, the original sample is divided into three sub-samples by geographical location: eastern, central and western. At the same time, considering that the retirement age of local officials in China is generally fixed, and local officials face greater audit pressure when they approach retirement, this paper further explores the impact of the age of local officials on the effectiveness of the pilot government environmental accountability policy. Finally, considering that technological progress will promote the transformation of traditional production and consumption modes to the direction of energy conservation and emission reduction, this paper conducts a mechanism analysis on the mediating effect of technological progress.

Study of the relationship between government environmental accountability policy and GTFP is empirical. The existence of a non-linear network relationship mechanism is significant. Future studies can construct DEA theoretical models to analyze internal logical relationships and explain empirical results. Using Chinese provincial data, future studies can enhance explanatory power with city-level or county-level data. Future research can also analyze the impact of regional heterogeneity on the relationship from an empirical perspective.

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