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The Influence of Environmental Policy on Green Total Factor Productivity in the Chinese Construction Industry

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Abstract

As an environmental policy, the Action Plan of Atmosphere Pollution Control in Beijing-Tianjin-Hebei and Surrounding Areas in Autumn and Winter (Action Plan of APC) was implemented in 2017, with the goal of achieving the sustainable growth of the regional economy. This study examines the effect of the Action Plan of APC on green total factor productivity (GTFP) in the Chinese construction industry employing a difference-in-differences (DID) approach. The findings indicate the following: Firstly, the environmental policy of the Action Plan of APC has significantly improved the GTFP of the aforementioned areas, and the result is still valid after robustness testing; secondly, the dynamic effect testing reveals that the influence follows an increasing trend over time; thirdly, due to the different degrees of marketization, the influence of the Action Plan of APC on GTFP in Chinese construction industry exhibits notable regional heterogeneity. From the perspectives of both the government and enterprises, this study offers recommendations for promoting the GTFP of China's construction industry. It also provides a novel framework for assessing the effect of environmental policies on the GTFP of the Chinese construction industry.

Keywords: air pollution; green growth; GTFP; DID model

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1. Introduction

Over the past decade, China has experienced rapid growth and achieved remarkable accomplishments. In 2023, China's GDP per capita reached 13,200 US dollars, while the per capita disposable expenditure rose to 41,300 RMB [1]. However, the extensive development mode causes a series of problems such as environmental degradation and resource scarcity. Key factors include the large-scale industrialization development, energy consumption dominated by petrochemical energy, and a widespread urbanization process, all of which have contributed to a rise in atmospheric pollutants and building dust, thereby resulting in serious air pollution problems [2]. Air pollution not only affects China's economic green growth but also poses potential risks to people's physical health. Studies have shown that air pollution significantly increases the likelihood of citizens suffering from respiratory, cardiovascular, and cerebrovascular diseases, and may even cause cancer [3–5]. The Sustainable Development Goals (SDGs), issued by the United Nations in 2015 [6], stress that the essence of green growth lies in decoupling economic growth from resource consumption and achieving sustainable development through improved resource productivity. To promote sustainable development, the Chinese government has set forth the "dual carbon" goals. It is clear that air pollution will escalate economic and social costs, hindering China from achieving its "dual carbon" targets [7]. Hence, air pollution has turned into an increasingly critical issue for society as a whole.

In order to control air pollution and promote the economic green transition, China has promulgated many air pollution control policies. In line with international standards, the Ministry of Environmental Protection introduced the PM2.5 indicator and formulated an atmosphere pollution control plan in 2012. The 14th Five-Year Plan, enacted by the National People's Congress (NPC), clearly states objectives to continuously improve environmental quality, implement coordinated multi-pollutant management, and establish a cross-regional coordinated prevention and control mechanism. It also emphasizes the strengthening of construction dust control and achieving the goal of basically eliminating heavy-pollution weather [8]. Thanks to the continuous efforts by the government over the years, remarkable progress has been made in reducing air pollution in specific regions in China.

However, as the largest urban agglomeration, Beijing-Tianjin-Hebei and the surrounding areas continue to suffer from severe haze episodes. According to monitored data from the government, the proportion of days with good air quality in the above regions was only 56.8% in 2016, which was 22% lower than the average level [9]. Due to the influence of meteorological conditions and pollution emissions, air pollution in the above regions was particularly severe during the autumn and winter months. For example, Beijing-Tianjin-Hebei and the surrounding areas had suffered from prolonged heavy-haze days, with PM2.5 levels soaring to 135 $\mu g/m^3$, 2.4 times the concentration found in other provinces. In response, the government promulgated the Action Plan of Atmosphere Pollution Control in Beijing-Tianjin-Hebei and Surrounding Areas in Autumn and Winter in 2017 (denoted as Action Plan of APC). The action plan is a targeted regional environmental policy in China, aimed at improving GTFP to foster the green growth of the regional economy [10]. To achieve this goal, the Action Plan of APC involves specific air pollution control measures, including adjustments to energy and industrial structures, dust control, and staggered production during heavy pollution days. The implementation of this policy marks a shift in China's atmospheric governance from nationwide air pollution control to improving air quality in key regions. Therefore, as a regional environmental policy, the Action Plan of APC holds significant research value.

As a fundamental sector, China's construction industry is a cornerstone in driving economic growth and elevating the standard of living for its people. In 2024, the added value of China's construction sector climbed to 8.9 trillion Yuan, accounting for 6.7% of the country's GDP [11]. However, the industry faces significant challenges, including high resource consumption, high pollution emissions, and low efficiency [12]. Carbon emissions and dust from the construction sector are major contributors to air pollution [13]. In 2022, a total of 2.42 billion tons of standard coal equivalents were consumed by the construction industry, making up 44.8% of China's total energy consumption. At the same time, the construction sector is also responsible for 5.13 billion tons of carbon emissions, making up 48.3% of the country's total carbon emissions [14]. As a major polluter, it is crucial for the construction industry to realize green growth by improving GTFP [15].

Environmental policies have been widely adopted to regulate China's economic transformation toward more sustainable pathways. However, scholars hold differing opinions about the impact of environmental policies on GTFP. Moreover, there is a notable absence of literature regarding the effect of environmental policies on the GTFP of the construction industry. In this context, we are particularly concerned with the effect of the Action Plan of APC on the GTFP of the Chinese construction industry. Specifically, after years of practice, does the Action Plan of APC help to boost GTFP? Are there any differences in the regions on GTFP within China's construction sector? These questions urgently need to be explored in theoretical and empirical dimensions. To address them, this paper constructs a DID approach to estimate the influence of the Action Plan of APC on the GTFP of the construction industry.

The rest of this study proceeds as follows: Section 2 reviews the literature on tools of environmental policy and GTFP and offers two hypotheses. Section 3 conducts methodology and discusses the data sources. Section 4 analyzes the research findings and demonstrates robustness tests. The final two sections present the conclusions and recommendations, respectively.

2. Literature and Research Hypotheses

2.1. Literature

2.1.1. Research on the Tools of Environmental Policy

Environmental policy refers to the laws, regulations, and standards established by the government to protect the environment, prevent pollution, and address other forms of environmental degradation [16]. In practice, once the issues are clearly defined and the objectives are clarified, the design and selection of environmental policy tools become key factors affecting the effectiveness of environmental policies. According to the degree of compulsion exerted on regulated entities, environmental policy tools can be categorized into three types: command-and-control tools, economic incentive tools, and voluntary tools [17]. Command-and-control tools are government-led and rely on the government's authority to directly regulate the discharge of pollution and the use of resources. Examples include the regulation of emission standards, green infrastructure and norms [18], and the implementation of environmental protection equipment [19]. Economic incentive tools are measures guided by the government, which uses economic means and market mechanisms to motivate enterprises to reduce pollution emissions while maximizing their own interests. Examples of economic incentive tools include environmental taxes, government subsidies, carbon trading, and pollution discharge permits [20]. Voluntary tools refer to the commitments or programs that a company voluntarily participates in to protect the environment [21].

2.1.2. Calculation Method of GTFP

Total factor productivity (TFP), initially introduced by Solow in 1957 [22], is used to evaluate the contributions of technological progress to economic growth. Nevertheless, TFP only considers input factors such as capital and labor, without accounting for the impact of energy use and environmental degradation on productivity [23]. With the increasingly severe environmental pollution, neglecting its "bad" output can lead to serious errors in TFP calculation, making it difficult to accurately evaluate economic performance. Therefore, it is necessary to consider the rigid constraints of environmental pollution on economic development and incorporate environmental pollution as an unexpected output into the productivity measurement framework, which is known as GTFP [24,25]. As far as calculation methods are concerned, there are mainly two approaches applied in the literature to calculate GTFP: One is stochastic frontier analysis (SFA). Some scholars have employed SFA to calculate GTFP, such as analyzing the growth of GTFP in the Chinese industrial sector [26], the regional innovation system efficiency [27], and the economic growth of prefecture-level cities [28]. Another is data envelopment analysis (DEA) with the Malmquist index [29–31], which introduces unexpected outputs into the production function to calculate GTFP. The DEA–Malmquist index has several advantages. It does not require a specific model form and can handle multiple inputs and outputs. Therefore, The DEA–Malmquist index is better suited for calculating GTFP. Now, the DEA-Malmquist index has become a popular approach among scholars to evaluate GTFP in industries such as transportation [32], manufacturing [7,33], agriculture [34,35], and the green development of cities [36].

2.1.3. Research on GTFP of Construction Industry

Scholars at home and abroad have conducted extensive research on GTFP in many fields. However, there are few of studies on the GTFP of the construction industry. Hu and Liu [37] utilized the Malmquist approach to study the TFP of the Australian construction sector over the past 21 years, and their findings showed that construction growth and carbon reduction could be achieved simultaneously through the learning of techniques from industry benchmarks. Xiang et al. [38] investigated the GTFP of the construction industry using the Malmquist-Luenberger approach. Their empirical research indicated that the GTFP of the construction sector exhibits V-shaped fluctuations. Furthermore, scholars have also found that the GTFP of the construction sector is relatively low [39] and exhibits regional heterogeneity [40].

2.1.4. Research on the Impact of Environmental Policy on GTFP

Scholars hold three distinct views regarding the impact of environmental policy on GTFP. The first view suggests that environmental policy hinders GTFP, based primarily on the "cost hypothesis" theory. According to this theory, the implementation of environmental policies may crowd out investment funds, impose additional burdens on enterprises, and result in negative externalities that hinder economic growth, thereby reducing enterprises' GTFP [41]. Fan et al. [42] found that the implementation of environmental policies increased compliance costs for enterprises and reduced enterprises' GTFP. Yan and Yu [43] found that government subsidy policy could easily lead to policy dependence among enterprises, which in turn weakened their innovation capabilities and reduced their production efficiency. The second view argues that stricter but well-designed environmental policies (pollutant emission permit trading schemes, market-based environmental taxes, etc.) can positively influence technological innovation, and improve a firm's GTFP in the long run [44]. For example, Shapiro and Walker [45] found the environmental taxes resulted in a 60% decline in air pollution and enhanced GTFP of the US manufacturing sector during 1990–2008. Yu et al. [46] studied how the NIIDZ policy implementation affected urban GTFP employing DID methodology. They found that the coefficient of the DID variable is significantly positive, meaning the enforcement of the NIIDZ policy enhanced urban GTFP. In addition, the coefficients of control variables, including human capital and urbanization level, significantly and positively influence urban GTFP. The third view suggests that there is an uncertain link between environmental policy and GTFP. Li. and Tao. [47] identified a U-type relationship between environmental policy and productivity, while Wang et al. [48] revealed an inverted U-type relationship between environmental policy and the GTFP of industrial firms from 2005 to 2015.

Through the studies mentioned above, it can be found that scholars have directly measured environmental policies with proxy variables such as environmental taxes, technology standards, financial subsidies, and then inferred the impact of environmental policies on GTFP. However, these studies do not clearly reveal the causal effect of environmental policies on GTFP. In addition, the literature on GTFP has primarily focused on industries such as manufacturing and agriculture, as well as other fields. Currently, there is a lack of research exploring how environmental policies influence the GTFP of the construction industry. This paper uses the Action Plan of APC as a quasi-natural experiment, employing panel data from 25 Chinese provinces covering the period from 2015 to 2022 to estimate the policy's impact on the GTFP of the construction industry of Beijing-Tianjin-Hebei and the surrounding areas.

Compared to previous research, the marginal contributions of our study are as follows: Firstly, the study empirically analyses the influences of the Action Plan of APC on the GTFP of the construction industry, which expands the research scope in this field. Secondly, the study explores the relationship between the Action Plan of APC and the GTFP of the construction industry, effectively addressing the endogenous problems brought by traditional estimation methods. Thirdly, the study examines the regionally heterogeneous effects of the Action Plan of APC on the GTFP of the construction industry. In a word, this research provides a novel framework for assessing the effects of environmental policies on the GTFP of the construction industry and offers valuable insights for policy formulation aimed at enhancing the GTFP of the construction industry.

2.2. Research Hypotheses

As an environmental policy, the purpose of the Action Plan of APC is to achieve a win-win benefit both for economic development and environmental protection by improving GTFP. This raises the following question: Will the enforcement of the Action Plan of APC affect the GTFP of the construction industry in Beijing-Tianjin-Hebei and the surrounding areas? Based on the existing literature and the policy context, this study believes that the Action Plan of APC will influence the GTFP of the construction industry through multiple channels. On one hand, in order to cope with this environmental policy, construction enterprises must transition from extensive production modes by increasing R&D investments and adopting green technologies [49]. Nevertheless, these added costs may hinder GTFP growth in the construction industry in the short term. In the long run, however, technological innovation will decrease operational costs, and construction enterprises will gradually benefit from these advancements [50]. On the other hand, policymakers would offer financial support for construction projects that utilize energy-saving technologies to reduce air pollution. These fiscal incentives can offset construction enterprises' additional costs in R&D and pollution control while stimulating their adoption of green technologies [51], ultimately enhancing GTFP. Therefore, we present the first hypothesis:

Hypothesis 1. *As an environmental policy, the Action Plan of APC will improve the GTFP of the construction industry.*

The intensity of the Action Plan of APC's implementation may vary across regions within Beijing-Tianjin-Hebei and the surroundings areas. These regions with higher air pollution likely face stricter environmental regulation than less polluted regions. Similarly, regional variations in marketization levels may also lead to different responses to environmental policy among construction enterprises [52]. The construction enterprises in highly marketized regions tend to respond actively to the Action Plan of APC and demonstrate stronger propensity for technological innovation investments. For example, they would develop green building materials and adopt energy-saving technologies to reduce pollution emissions during construction. This will help to improve GTFP. However, in regions with a low degree of marketization, construction enterprises tend to respond passively to the Action Plan of APC, lacking motivation for technological innovation. These enterprises will continue relying on traditional technologies and equipment with higher energy consumption in construction, making it more difficult to improve GTFP. Consequently, the influence of the Action Plan of APC on the construction industry's GTFP demonstrates significant regional heterogeneity. Thus, the second hypothesis is put forward:

Hypothesis 2. *The impact of the Action Plan of APC on the GTFP of the construction industry exhibits significant regional heterogeneity.*

3. Methodology and Data

3.1. Research Model

Compared to previous environmental policies [53–55], the Action Plan of APC possesses two distinct characteristics. Firstly, its timing: Unlike other environmental policies, which typically require several years of discussion before being introduced (such as the policy for the "Five-Year-Plan"), the Action Plan of APC, as a response to heavy air pollution during the months of autumn and winter in 2016, was launched rapidly in August 2017. Consequently, construction enterprises could neither anticipate the timing of environmental policy implementation, nor effectively intervene in government decision-making in the short term. Thus, the implementation of the Action Plan of APC constitutes a significant exogenous shock to the construction industry. Secondly, in terms of the scope, the implementation regions of this policy are clearly defined, encompassing only Beijing-Tianjin-Hebei and its surroundings. The implementation of this policy can be viewed as a quasi-natural experiment.

Referring to Li et al. [56], this paper estimates the influence of the Action Plan of APC on the GTFP of the construction industry by employing the difference-in-differences (DID) model. The DID model is specified as the following:

$$GTFP_{it} = \beta_0 + \beta_1 treat_i \times time_t + \beta_2 treat_i + \beta_3 time_t + \beta_4 control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In Model (1), $GTFP_{it}$ is the dependent variable, representing the construction industry's GTFP of province i at time t. $treat_i$ is the group dummy variable, representing whether the province is implementing the Action Plan of APC. $time_t$ is time dummy variable that indicates whether this policy has been issued in year t. $treat_i \times time_t$ is the core independent variable, indicating whether the Action Plan of APC has been implemented in province i at time t. $control_{it}$ represents the control variables influencing the GTFP of the construction industry. μ_i and λ_t are the regional effect and time effect, respectively. ε_{it} is a random interference term. $\beta_0 \ldots \beta_4$ are coefficients to be estimated. To improve the precision of the analysis, we adopt a fixed-effects DID model to estimate the effect of the Action Plan of APC on the construction industry's GTFP.

3.2. Variable Definition

3.2.1. Dependent Variable

The dependent variable is the construction industry's GTFP, which is measured following Giannetti et al. [57] and Krishnan et al. [58] with the Cobb-Douglas production function:

$$\ln CY_{it} = \alpha_{0t} + \alpha_{1t} \ln K_{it} + \alpha_{2t} \ln L_{it} + \alpha_{3t} \ln M_{it} + \varepsilon_{it} \quad (2)$$

In Model (2), CY indicates the output value per unit of carbon emissions (billions of Yuan) from the construction industry. K is capital, measured by construction enterprise assets (billions of Yuan). L represents labor, measured by the number of construction industry employees (tens of thousands of people). M signifies the intermediate investment of the construction industry, measured by the total power of construction machinery and equipment at year end (tens of thousands of kilowatts). ε_{it} is the random term. The model is regressed with group data by year. The GTFP of the construction sector is derived from the residuals of the Cobb-Douglas production function.

3.2.2. Independent Variables

Time dummy variable (*time*): *time* is set in line with the implementation year of the Action Plan of APC. Since this policy was implemented in 2017, this study sets *time* equal to 1 for 2017 and later years (i.e., *time* = 1), while it is equal to 0 for years prior to 2017 (i.e., *time* = 0).

Group dummy variable (*treat*): With reference to the existing empirical studies of Qian et al. [59] and Wan et al. [60], this study sets a group dummy variable (*treat*) based on whether the province is affected by the Action Plan of APC. If the province is influenced by the Action Plan of APC, then it is classified into the treatment group (*treat* = 1). Otherwise, the province is set as the control group (*treat* = 0). The treatment group is comprised of six provinces (with Beijing, Tianjin, Hebei, Shanxi, Shandong, and Henan), which are impacted by the Action Plan of APC. Considering that the central government issued the Action Plan of Atmosphere Pollution Control in Yangzi River Delta Region in Autumn and Winter in November 2018, this study excludes the provinces in the Yangzi River Delta Region to guarantee that the analysis results reflect the net effect of the Action Plan of APC in 2017. Additionally, due to the missing data, the Tibet autonomous region is excluded. Therefore, the remaining 19 provinces (municipalities and autonomous regions) that are not impacted by the environmental policy are assigned to the control group.

The policy-affected variable ($treat_i \times time_t$): $treat_i \times time_t$, the core independent variable, represents the interaction between $time_t$ and $treat_i$ and is used to measure the action plan's impact on the construction industry's GTFP. If province i is subject to the Action Plan of APC in year t, then $treat_i \times time_t$ is 1 (i.e., $treat \times time = 1$); otherwise, $treat_i \times time_t$ is 0 (i.e., $treat \times time = 0$).

3.2.3. Control Variables

Considering the additional determinants of the construction industry's GTFP, this study incorporates five control variables following the existing research [61]: energy consumption structure (Energy), power equipment rate (Power), human capital (Hc), proportion of state-owned economy (Prop), and urbanization rate (Urban). Table 1 shows the specific definitions of variables.

Table 1. Definitions of variables.

Variable Type	Variable Name	Definitions
Dependent variable	GTFP	Green total factor productivity
Independent variables	time	If the year is prior to 2017, then time = 0; otherwise, time = 1
	treat	Treat = 1 if the province belongs to Beijing-Tianjin-Hebei and the surrounding areas; otherwise, treat = 0
	$treat \times time$	If province i implements the Action Plan of APC in year t, then $treat \times time = 1$; otherwise, $treat \times time = 0$
Control variables	Energy	The share of fossil fuels in total energy consumption
	Power	The power equipment rate of the construction industry
	Hc	Labor productivity of construction enterprises (RMB/person)
	Prop	The proportion of the output value of state-owned construction companies in the construction sector
	Urban	The ratio of the urban population to the total population

3.3. Data Resource

In our paper, 2015 to 2022 panel data from 25 Chinese provinces are chosen for empirical analysis. The missing data are supplemented by the average interpolation method. The data are sourced from the China Environmental Statistical Yearbook (2016–2023), the China Statistical Yearbook (2016–2023), the China Construction Industry Statistical Yearbook (2016–2023), and the statistical yearbook of each province (2016–2023). On the one hand, the statistical yearbook data are officially compiled by national and local statistical authorities, carrying legally binding force that meets academic credibility standards. On the other hand, these datasets have gained robust validation through scholarly practice, with their efficacy in China's environmental policy assessments being substantiated by peer-reviewed studies [20,62,63].

To mitigate heteroscedasticity, the natural logarithm of the variables GTFP, Power, and Hc are applied. Table 2 presents the descriptive statistics. Key findings show that the lnGTFP mean is 1.753 (SD = 0.622), ranging from 0.106 to 3.623. This indicates that lnGTFP has a significant difference over the sample period. Additionally, the range of fluctuations for the control variables is also quite large. Therefore, it is essential to examine how the Action Plan of APC affects the GTFP of the construction industry.

Table 2. Descriptive statistics.

Variables	Obs	Min	Max	Mean	Median	SD
lnGTFP_LP	240	0.106	3.623	1.753	1.711	0.622
Energy	240	0.052	0.925	0.589	0.598	0.168
lnPower	240	0.693	2.944	1.578	1.609	0.510
lnHc	240	12.339	13.591	12.898	12.875	0.269
Prop	240	0.010	0.541	0.167	0.155	0.101
Urban	240	0.429	0.893	0.627	0.610	0.107

4. Empirical Analysis

4.1. Benchmark Regression Results

In accordance with Model (1), we employ a DID approach to measure the influence of the Action Plan of APC on the GTFP of the construction sector. Table 3 presents the benchmark analysis, where the dependent variable is lnGTFP of the construction industry calculated via the Panel LP-DID method. Column (1) reveals that the coefficient of $treat \times time$ is 0.149. In contrast, when control variables are incorporated, the regression coefficient of $treat \times time$ in column (6) is 0.085. The benchmark regression results demonstrate that the coefficients of $treat \times time$ are positive at the 1%, 5%, and 10% significance levels across all columns. This suggests that the GTFP of the construction industry in the treatment group is significantly increased after the promulgation of the Action Plan of APC. This result aligns with that of Yang et al. [64], who claimed a 7.4% improvement in GTFP following environmental policies. The empirical evidence strongly supports Hypothesis 1.

The estimated coefficients for the control variables reveal significant relationships with the construction industry's lnGTFP. Firstly, energy consumption structure is negatively correlated with lnGTFP, and significant at the 1% level, indicating that greater reliance on petrochemical energy substantially reduces GTFP. At the same time, power equipment rate (lnPower) is positively correlated with lnGTFP, demonstrating that energy-efficient equipment adoption effectively enhances green productivity. The human capital (lnHc) of construction enterprises displays a significantly positive relationship with lnGTFP and is significant at the level of 1%, suggesting that high-quality workers in construction enterprises can quickly understand environmental policy and master green construction technologies, thus enhancing GTFP. What is more, the state-owned economy proportion (Prop) correlates negatively with lnGTFP, implying state-owned enterprises' preference for extensive production models and comparatively weaker innovation capabilities compared to private firms. Urbanization is also negatively correlated with the construction industry's GTFP, significantly at the 5% level, revealing that urbanization decreases GTFP. Urbanization substantially increases infrastructure and building demand, generating significant construction waste (e.g., concrete, steel, and wood debris) and dust emissions, which are key factors in reducing the GTFP of the construction industry.

Table 3. Benchmark regression results.

Variables	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP
	(1)	(2)	(3)	(4)	(5)	(6)
treat × *time*	0.149 ***	0.080 *	0.078 *	0.097 **	0.104 **	0.085 **
	(2.87)	(1.94)	(1.88)	(2.35)	(2.46)	(1.99)
time1	0.503 ***	0.318 ***	0.327 ***	0.210 ***	0.209 ***	0.359 ***
	(11.44)	(8.20)	(8.30)	(3.43)	(3.40)	(3.77)
treat1	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Energy		−1.607 ***	−1.597 ***	−1.540 ***	−1.524 ***	−1.520 ***
		(−10.42)	(−10.36)	(−10.01)	(−9.83)	(−9.90)
lnPower			0.007	0.006	0.007	0.004
			(1.22)	(1.15)	(1.21)	(0.71)
lnHc				0.242 **	0.244 **	0.283 ***
				(2.45)	(2.46)	(2.82)
Prop					−0.171	−0.250
					(−0.82)	(−1.19)
Urban						−2.154 **
						(−2.05)
_cons	1.485 ***	2.546 ***	2.501 ***	−0.608 **	−0.602 **	0.156 **
	(49.66)	(24.36)	(22.54)	(−0.48)	(−0.47)	(0.12)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.945	0.966	0.967	0.968	0.968	0.969
N	208	208	208	208	208	208

Note: *t* statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2. Dynamic Effect Test

For assessing the dynamic effects of the Action Plan of APC on the construction industry's GTFP, this paper introduces new dummy time variables (time2018, time2019, time2020, time2021, and time2022). Each dummy equals 1 for its respective year (e.g., time2018 = 1 for 2018). Then, the dummy variables time2018 to time2022 are used as interactive items with the grouped variable "treat". Table 4 exhibits the results of the dynamic effect test. From Table 4, we can see that the majority of coefficients of *treat* × *time*2018, *treat* × *time*2019, *treat* × *time*2020, *treat* × *time*2021, and *treat* × *time*2022 are significant at the 1%, 5%, and 10% levels, reflecting a strengthening effect on the construction industry's GTFP over time.

Table 4. The dynamic effect: impact of Action Plan of APC on GTFP.

Variables	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP
	(1)	(2)	(3)	(4)
treat × *time*	0.131 **	0.084 *		
	(2.24)	(1.78)		
treat × *time*2018			0.184 *	0.055
			(1.80)	(0.94)
treat × *time*2019			0.294 ***	0.063 *
			(2.87)	(1.06)
treat × *time*2020			0.394 ***	0.111 *
			(3.85)	(1.81)
treat × *time*2021			0.550 ***	0.131 **
			(5.38)	(2.11)

Table 4. *Cont.*

Variables	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP	lnGTFP_LP
	(1)	(2)	(3)	(4)
$treat \times time2022$			0.647 ***	0.209 ***
			(6.32)	(3.35)
_cons	1.485 ***	0.408	1.660 ***	−3.151 ***
	(49.23)	(0.31)	(93.80)	(−3.59)
Control variables	No	Yes	No	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes
R^2	0.944	0.969	0.887	0.965
N	208	208	208	208

Note: *t* statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Based on the evidence, the Action Plan of APC significantly boosted the construction sector's GTFP in the treatment group relative to the control group. Furthermore, dynamic analysis reveals an intensifying impact of the policy on construction GTFP growth in the treatment group.

4.3. Robustness Test

4.3.1. Parallel Trend Test

The precondition for employing the DID method hinges on satisfying the parallel trend assumption: Before the Action Plan of APC is executed, the GTFP of the construction industry in the two groups must maintain a basically parallel change trend. To ensure this basic assumption, this study takes the implementation year of 2017 for the Action Plan of APC as the base year and plots the time trend chart of GTFP for both groups.

The parallel trend test is shown in Figure 1. We can see that the GTFP of the construction industry evolves in a statistically parallel manner in the treatment and control groups before 2017. However, a significant divergence emerges: The treatment group exhibits accelerated GTFP growth, while the control group maintains gradual improvement after 2017. This visual evidence supports the validity of the parallel trend assumption, confirming the appropriateness of the DID specification for our benchmark model.

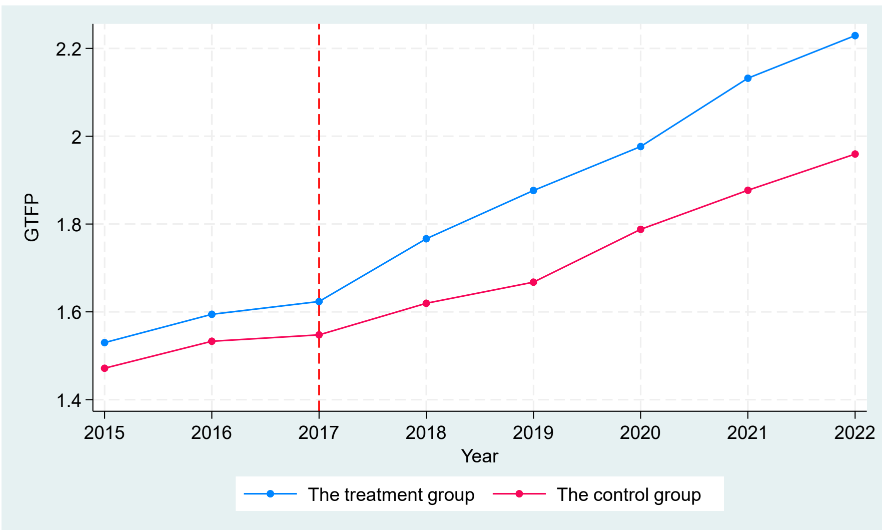

Figure 1. Parallel trend test.

4.3.2. Replacing the Dependent Variable

This study utilizes lnGTFP_FE (fixed-effects method) as a replacement variable for lnGTFP_LP to recalculate GTFP. Table 5 illustrates the regression results for replacing the dependent variable. After replacing the dependent variable, the coefficients of $treat \times time$ are positive, with significance levels of 5% and 10%, respectively, verifying the reliability of the benchmark regression.

Table 5. DID regressions for replacing dependent variable.

Variables	**lnGTFP_FE**	**lnGTFP_FE**
	(1)	**(2)**
$treat \times time$	0.116 **	0.104 *
	(2.06)	(1.88)
_cons	2.821 ***	3.827 ***
	(97.19)	(3.02)
Control variables	No	Yes
Time fixed effect	Yes	Yes
Province fixed effect	Yes	Yes
R^2	0.959	0.977
N	208	208

Note: "Control variables" represents the control of a series of control variables; the same below. t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3.3. Counterfactual Test

Referring to Qiu et al. [65], this study changes the year of the Action Plan of APC implementation to 2016 and 2015, respectively, and constructs a counterfactual framework to demonstrate the reliability of the causal relationship between the Action Plan of APC's implementation and the GTFP of the construction industry. Counterfactual tests have proved that if the time of the Action Plan of APC implementation was advanced to 2016 or 2015, the coefficients for $treat \times time2016$ and $treat \times time2015$ would both be statistically insignificant. This suggests that the GTFP growth in the construction industry is caused by the Action Plan of APC rather than random factors. Therefore, the results of this paper are quite reliable.

4.3.4. Heterogeneity Test

While empirical results confirm that the Action Plan of APC significantly enhanced construction GTFP in treated provinces, it should be pointed out that the Action Plan of APC is a selective environmental policy that mainly relies on government intervention in enterprises rather than the market. The implementation effect of the Action Plan of APC is highly correlated with local government intervention in enterprises. Shao [66] demonstrated that under different degrees of local government intervention, the exertion effect of CETS policy had great differences. Thus, this study further tests the heterogeneous effects of the Action Plan of APC on the construction industry's GTFP in the treatment group. Following Zhang et al. [67], the Marketization Index for China's Provinces [68] is employed to assess the level of local government intervention in construction enterprises within the treatment group. A lower score in the Marketization Index indicates a higher level of government intervention in construction enterprises.

Firstly, this study matches the samples using the 2016 data from the Marketization Index for China's Provinces. Secondly, based on the Marketization Index of each province in the treatment group, the samples are divided into two groups: one with a high degree of marketization (Beijing and Tianjin) and another with a low degree of marketization (Shangdong, Hebei, Shanxi, Henan). Thirdly, this study constructs a DID model to examine the influence of the Action Plan of APC on construction GTFP in the two groups. Table 6 reports the results of group regression.

Table 6. Impact of Action Plan of APC on GTFP of Construction Industry: Group Regression Results.

Groups	Group with High Degree of Marketization		Group with Low Degree of Marketization	
	(1)	**(2)**	**(3)**	**(4)**
Variables	lnGTFP_LP	lnGTFP_FE	lnGTFP_LP	lnGTFP_FE
treat × *time*	0.237 ***	0.233 ***	0.100 **	0.105 **
	(3.03)	(3.01)	(1.79)	(2.01)
_cons	−4.148 ***	−0.848	0.667	4.917 ***
	(−4.59)	(−0.95)	(0.36)	(2.86)
Control variables	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes
R^2	0.969	0.976	0.958	0.972
N	176	176	192	192

Note: t statistics in parentheses. ** $p < 0.05$, *** $p < 0.01$.

Column (1) and column (3) of Table 6 illustrate that the estimated coefficients of *treat* × *time* are significantly positive at the 1% level in the high-marketization group and at the 5% level in the low-marketization group. Meanwhile, the coefficient of *treat* × *time* in column (1) is greater than that in column (3), which means that the Action Plan of APC has a more significant influence on the GTFP of the construction industry in the high-marketization group compared to the low-marketization group. To verify the robustness of the results, this study substitutes lnGTFP_FE for lnGTFP_LP to recalculate the construction industry's GTFP. The coefficient of *treat* × *time* in column (2) is larger than that in column (4), which further supports the robustness of our conclusion. How to explain the interesting finding? A possible reason is that local governments with a high degree of marketization can fully utilize market mechanisms to minimize direct intervention in microeconomic activities, creating a fair policy environment for enterprise competition. This will motivate construction enterprises to focus on technological innovation and R&D, thereby improving productivity. Additionally, the pressure of market competition forces construction enterprises to reduce costs and adopt green technologies, further enhancing GTFP. In summary, due to the different degrees of marketization, the influence of the Action Plan of APC on the GTFP of the construction industry exhibits regional heterogeneity. This result aligns with the findings of Shao [66], who argues that the role of the carbon emissions policy was more significant in the high-marketization region than in the low-marketization region. As a result, Hypothesis H2 is verified in this study.

5. Conclusions

Using the DID model, this study has investigated how the Action Plan of APC implemented in 2017 affected the GTFP of the construction industry from 2015 to 2022 based on provincial-level data in China. This study leads to the following main findings:

First, our findings indicate that the Action Plan of APC significantly increases the GTFP of the construction industry in treatment group by 8.5%. The benchmark regression results are significantly positive, irrespective of whether control variables are included. Moreover, the conclusion holds up through robustness tests, which supports Hypothesis 1.

Second, the empirical findings indicate that the control variables have different effects on the construction industry's GTFP. The energy consumption structure and urbanization rate have a negative influence on the construction industry's GTFP at the 1% and 5% significance levels, suggesting that a fossil fuel-dominated energy structure and large-scale urbanization decreased the construction industry's GTFP. On the other hand, human capital and the rate of power equipment have a positive influence on the GTFP of the construction industry, meaning high-quality workers and the use of energy-saving equipment can effectively improve green productivity. Third, from a dynamic perspective, we introduce new dummy variables to examine the model's dynamic impacts. Our findings suggest that the influence of the Action Plan of APC on the construction industry's GTFP in the treatment group is on an upward trend. Fourth, the Action Plan of APC exerts a heterogeneous impact on GTFP in the treatment group, which supports Hypothesis H2. This study demonstrates that the high-marketization group (Beijing, Tianjin) experiences a greater policy effect than the low-marketization group (Shandong, Hebei, Henan, Shanxi).

6. Recommendations

Firstly, the government should expand the implementation of the Action Plan of APC to more regions to accelerate the green transition of China's construction industry. Our empirical findings demonstrate that the Action Plan of APC can boost the GTFP of the construction industry, indicating that this environmental policy successfully balances economic development with environmental protection, thereby promoting the green growth of the construction sector. Therefore, the government should consider extending the scope of the policy to realize green growth across China's construction industry.

Secondly, local governments need to transform their functions and fully leverage market mechanisms. Our empirical study shows that the construction industry's GTFP is more positively influenced by the Action Plan of APC in the high-marketization group. Therefore, the local governments should streamline administration and delegate power, reduce direct intervention in microeconomic activities, and take more market-oriented measures to incentivize construction enterprises to reduce pollution emissions, thereby achieving greener growth in the sector.

Thirdly, construction enterprises should shift towards a production mode driven by green technology innovation. Construction companies should actively adopt new green construction technologies, such as construction industrialization, BIM, and intelligent building technologies, as well as utilize recyclable and renewable building materials. The adoption of these new technologies and materials can not only transform the energy consumption structure dominated by petrochemical energy but also effectively reduce environmental pollution caused by building dust and construction waste.

This study acknowledges two primary limitations. Firstly, while focusing on the action plan as a key atmospheric governance policy, we have not yet discussed other atmospheric governance policies that may also influence the construction industry's GTFP. Future research should assess the synergistic effects of multiple policies on GTFP in the construction industry. Secondly, there may be mediating mechanisms through which the Action Plan of APC affects the GTFP of the construction sector, which warrants further exploration.

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References

1. The State Council of the People's Republic of China. China's Economic, Social Progress in 2024. Available online: https://english.www.gov.cn/archive/statistics/202502/28/content_WS67c17e9dc6d0868f4e8f0236.html (accessed on 9 March 2025).
2. Farzadkia, M.; Mahvi, A.H.; Baghani, A.N.; Sorooshian, A.; Delikhoon, M.; Sheikhi, R.; Ashournejad, Q. Municipal solid waste recycling: Impacts on energy savings and air pollution. *J. Air Waste Manag. Assoc.* **2021**, *71*, 737–753. [CrossRef]
3. Gao, J.; Ying, C.; Hu, L.; Lin, Z.; Xie, H. Assessing the Effects of Environmental Smog Warning Policy on Preventing Traffic Deaths Based on RDD Strategy. *Atmos* **2023**, *14*, 1043. [CrossRef]
4. Zhao, Y.; Wang, Y.; Zhang, X.; Fang, J.; Song, P. Study of winter haze pollution events in Jinan (China). *Urban Clim.* **2023**, *49*, 101516. [CrossRef]
5. Kumi, L.; Jeong, J.; Jeong, J.; Lee, J. Empirical Analysis of Dust Health Impacts on Construction Workers Considering Work Types. *Buildings* **2022**, *12*, 1137. [CrossRef]
6. Marvi, H.; Kalwar, S.; Talpur, M.A.H.; Memon, I.A.; Soomro, M.; Ahsan, N. Cultivating Community: Addressing Social Sustainability in Rapidly Urbanizing Hyderabad City, Pakistan. *Societies* **2024**, *14*, 161. [CrossRef]
7. Wang, L.M.; Li, S.H.; Lv, Y.Q. Influence of local governments on the greening of the manufacturing sector: A perspective on environmental governance objectives. *Heliyon* **2024**, *10*, e23801. [CrossRef]
8. National Bureau of Statistics. *The Construction Industry Data*; National Bureau of Statistics: Beijing China, 2021.
9. Wang, K. The Ministry of Environmental Protection Released the National Air Quality Status for 2016. Available online: https://www.mee.gov.cn/hjzl/dqhj/qgkqzlzk/201701/t20170123_395142.shtml (accessed on 23 January 2017).
10. Ministry of Ecology and Environment of the People's Republic of China. Notice of the State Council on Issuing the Action Plan to Comprehensive Control Autumn and Winter Air Pollution in Beijing-Tianjin-Hebei and Surrounding Regions 2017–2018. Available online: https://www.mee.gov.cn/gkml/hbb/bwj/201708/t20170824_420330.htm. (accessed on 21 August 2017).
11. National Bureau of Statistics of China. Statistical Communiqué on National Economic and Social Development for 2024. Available online: https://www.stats.gov.cn/sj/zxfb/202502/t20250228_1958817.html (accessed on 28 February 2025).
12. Zhou, W.; Li, Q.; Cui, X. conversion efficiency of new and old kinetic energy and its impact factors in China's construction industry based on Malmquist index method. *J. Environ. Prot. Ecol.* **2022**, *23*, 1309–1320.
13. Manzhilevskaya, S. Dust Pollution in Construction Sites in Point-Pattern Housing Development. *Buildings* **2024**, *14*, 2991. [CrossRef]
14. China Association of Building Energy Efficiency. China's Urban and Rural Construction Field Carbon Emissions Research Report (2024). Available online: https://www.cabee.org/site/content/25288.html (accessed on 20 January 2025).
15. Yang, S.; Shen, J.; Deng, X.; Lu, K.; Liu, Z.; Cheng, B. Digital economy revolutionizing green total factor productivity in construction industry. *Technol. Forecast. Soc. Change* **2024**, *206*, 123564. [CrossRef]
16. Biermann, F. The future of 'environmental' policy in the Anthropocene: Time for a paradigm shift. *Environ. Politics* **2021**, *30*, 61–80. [CrossRef]
17. Chai, S.; Zhang, Z.; Ge, J. Evolution of environmental policy for China's rare earths: Comparing central and local government policies. *Resour. Pol.* **2020**, *68*, 101786. [CrossRef]
18. Baig, F.; Talpur, A.; Das, G.; Talpur, M.A.H.; Lee, J. Willingness to Shift towards Biogas-fueled Bus Rapid Transit in Karachi, Pakistan. *KSCE J. Civ. Eng.* **2024**, *28*, 1501–1512. [CrossRef]
19. Honggui, G.; Yingying, X.; Yuke, Z. Impact of Command Controlled Environmental Regulation on Carbon Price: Experiment Based on Central Environmental Protection Inspector. *J. China Univ. Geosci. (Soc. Sci. Ed.)* **2022**, *22*, 54–66.
20. Chen, T.; Tian, Y.; Zhang, Z.; Yu, J. Study on the Coupling and Coordination Relationship Between Urban Living Environment and Economic Development. *Buildings* **2024**, *14*, 3914. [CrossRef]
21. Segerson, K.; Miceli, T.J. Voluntary Environmental Agreements: Good or Bad News for Environmental Protection? *J. Environ. Econ. Manag.* **1998**, *36*, 109–130. [CrossRef]
22. Solow. Technical Change And The Aggregate Production Function. *Rev. Econ. Stat.* **1957**, *39*, 310–320. [CrossRef]
23. Lu, C.H.; Zhao, P.T.; Lin, X.Q. Does green technology innovation contribute to energy efficiency improvement: Empirical evidence from Chinese cities. *Energy Rep.* **2023**, *9*, 462–473. [CrossRef]
24. Umetsu, C.; Chakravorty, L.U. Efficiency and Technical Change in the Philippine Rice Sector: A Malmquist Total Factor Productivity Analysis. *Am. J. Agric. Econ.* **2011**, *85*, 943–963. [CrossRef]

25. Ahmed, N.; Hamid, Z.; Mahboob, F.; Rehman, K.U.; Ali, M.S.E.; Senkus, P.; Wysokinska-Senkus, A.; Sieminski, P.; Skrzypek, A. Causal Linkage among Agricultural Insurance, Air Pollution, and Agricultural Green Total Factor Productivity in United States: Pairwise Granger Causality Approach. *Agriculture* **2022**, *12*, 1320. [CrossRef]
26. Cui, H.R.; Wang, H.R.; Zhao, Q.Z. Which factors stimulate industrial green total factor productivity growth rate in China? An industrial aspect. *Greenh. Gases-Sci. Technol.* **2019**, *9*, 505–518. [CrossRef]
27. Barra, C.; Ruggiero, N. How do dimensions of institutional quality improve Italian regional innovation system efficiency? The Knowledge production function using SFA. *J. Evol. Econ.* **2022**, *32*, 591–642. [CrossRef]
28. Yu, Y.; Liu, A.; Gong, Y. Target of Local Economic Growth and Total Factor Productivity. *Econ. Res. J.* **2019**, *35*, 26–42+202.
29. Krüger, J.J. The global trends of total factor productivity: Evidence from the nonparametric Malmquist index approach. *Working Paper* **2001**, *55*, 265–286. [CrossRef]
30. Nabavieh, A.; Cyrus, K.M.; Gholamiangonabadi, D.; Gholamveisy, S. Assessing productivity changes using the bootstrapped Malmquist index: The case study of the Iranian construction industry. In Proceedings of the International Conference on Industrial Engineering and Operations Management, Toronto, ON, Canada, 23–25 October 2019; pp. 376–386.
31. Mai Lan, P.; Thuy Trang, N.; Khac Minh, N. FDI spillover effect on the green productivity of Vietnam manufacturing firms: The role of absorptive capacity. *J. Appl. Econ.* **2024**, *27*, 2382653. [CrossRef]
32. Yang g, X.H.; Jia, Z.; Yang, Z.M. How does technological progress impact transportation green total factor productivity: A spatial econometric perspective. *Energy Rep.* **2021**, *7*, 3935–3950. [CrossRef]
33. Zhong, Y.; Sun, B. Research on relationship between FDI and Green Total Factor Productivity Based on Fixed Effects Model——China's Manufacturing Data. In Proceedings of the 2020 Management Science Informatization and Economic Innovation Development Conference, Guangzhou, China, 18–20 December 2020.
34. Sun, Y.C. Environmental regulation, agricultural green technology innovation, and agricultural green total factor productivity. *Front. Environ. Sci.* **2022**, *10*, 955954. [CrossRef]
35. Hamid, S.; Wang, Q.; Wang, K. The spatiotemporal dynamic evolution and influencing factors of agricultural green total factor productivity in Southeast Asia (ASEAN-6). *Environ. Dev. Sustain.* **2025**, *27*, 2469–2493. [CrossRef]
36. Wu, C.; Shi, R.; Luo, Y. Does smart city pilot improve green total factor productivity? Evidence from Chinese cities. *Environ. Sci. Pollut. Res.* **2024**, *31*, 7380–7395. [CrossRef] [PubMed]
37. Hu, X.; Liu, C. Total Factor Productivity Measurement with Carbon Reduction. *Eng. Constr. Archit. Manag.* **2017**, *24*, 575–592. [CrossRef]
38. Xiang, P.; Xie, Y.; Li, Z. GTFP and Influencing Factors of Construction Industry from Low Carbon Perspective. *J. Ind. Technol. Econ.* **2019**, *38*, 57–63. [CrossRef]
39. Chen, Y. Research on the Temporal and Spatial Evolution and Driving Factors of Green Total Factor Productivity in the Construction Industry—Empirical analysis based on the Yangtze River Economic Belt from 2008 to 2017. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *526*, 012010. [CrossRef]
40. Hua, J.; Wang, Y. Green Total Factor Productivity Analysis for China's Construction Industry- Based on Panel Data From 30 Provinces. *Math. Pract. Theory* **2020**, *50*, 297–305.
41. Abate, T.G.; Rasmus, N.; Tveterås, R. Stringency of environmental regulation and aquaculture growth: A cross-country analysis. *Aquacult. Econ. Manag.* **2016**, *20*, 201–221. [CrossRef]
42. Fan, H.; Tao, S.; Hashmi, S.H. Does the Construction of a Water Ecological Civilization City Improve Green Total Factor Productivity? Evidence from a Quasi-Natural Experiment in China. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1829. [CrossRef] [PubMed]
43. Yan, Z.; Yu, J. Government subsidy and firms' total factor productivity:a comparative analysis of emerging industry and traditional manufacturing industry. *Ind. Econ. Res.* **2017**, *86*, 1–13.
44. Liao, Z. Environmental policy instruments, environmental innovation and the reputation of enterprises. *J. Clean. Prod.* **2018**, *171*, 1111–1117. [CrossRef]
45. Shapiro, J.; Walker, R. Why Is Pollution from US Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade. *Am. Econ. Rev.* **2018**, *108*, 3814–3854. [CrossRef]
46. Yu, H.; Zhang, J.; Xu, N. Does National Independent Innovation Demonstration Zone Construction Help Improve Urban Green Total Factor Productivity? A Policy Assessment from China. *Sustainability* **2023**, *15*, 7417. [CrossRef]
47. Li, L.; Tao, F. Selection of Optimal Environmental Regulation Intensity for Chinese Manufacturing Industry-Based on the Green TFP Perspective. *J. China Ind. Econ.* **2012**, *5*, 70–82.
48. Wang, L.; Chen, X.; Yao, X.; Li, X. The Influences of Environmental Regulation on Green Economic Performance of Industrial Enterprises. *East China Econ. Manag.* **2018**, 78–81.
49. Cheng, Z.; Kong, S. The effect of environmental regulation on green total-factor productivity in China's industry. *Environ. Impact Assess. Rev.* **2022**, *94*, 106757. [CrossRef]

50. Yang, X.; Li, Z.; Qiu, Z.; Wang, J.; Liu, B. ESG performance and corporate technology innovation: Evidence from China. *Technol. Forecast. Soc. Change* **2024**, *206*, 123520. [CrossRef]
51. Jiang, Z.; Xu, C. Policy incentives, government subsidies, and technological innovation in new energy vehicle enterprises: Evidence from China. *Energy Policy* **2023**, *177*, 113527. [CrossRef]
52. Wang, D.; Tarasov, A.; Zhang, H. Environmental regulation, innovation capability, and green total factor productivity of the logistics industry. *Kyb* **2022**, *52*, 688–707. [CrossRef]
53. Chen, J.; Qi, J.; Ga, M.; Li, Y.; Song, M. Economic growth, air pollution, and government environmental regulation: Evidence from 287 prefecture-level cities in China. *Technol. Econ. Dev. Econ.* **2021**, *27*, 1–23. [CrossRef]
54. Jafari, A.J.; Charkhloo, E.; Pasalari, H. Urban air pollution control policies and strategies: A systematic review. *J. Environ. Health Sci. Eng.* **2021**, *19*, 1911–1940. [CrossRef]
55. Cai, S.Y.; Ma, Q.; Wang, S.X.; Zhao, B.; Brauer, M.; Cohen, A.; Martin, R.V.; Zhang, Q.Q.; Li, Q.B.; Wang, Y.X.; et al. Impact of air pollution control policies on future PM2.5 concentrations and their source contributions in China. *J. Environ. Manag.* **2018**, *227*, 124–133. [CrossRef]
56. Li, Z.; Xie, S.; Wei, Z. The Impact of China's New Infrastructure Development on Urban Innovation Quality—A Quasi-Natural Experiment of Smart City Pilots. *Buildings* **2024**, *14*, 548. [CrossRef]
57. Giannetti, M.; Liao, G.; Yu, X. The Brain Gain of Corporate Boards: Evidence from China. *JFin* **2014**, *70*, 1629–1682. [CrossRef]
58. Krishnan, K.; Nandy, D.K.; Puri, M. Does Financing Spur Small Business Productivity? Evidence from a Natural Experiment. *Rev. Financ. Stud.* **2014**, *28*, 1768–1809. [CrossRef]
59. Qian, X.S.; Kang, J.; Tang, Y.; Cao, X. Industrial Policy, Efficiency of Capital Allocation and Firm's Total Factor Productivity—Evidence from a Natural Experiment in China. *China Ind. Econ.* **2018**, *8*, 42–59.
60. Wan, P.; Yang, M.; Chen, L. How Do Environmental Technology Standards Affect the Green Transition of China's Manufacturing Industry—A Perspective from Technological Transformation. *China Ind. Econ.* **2021**, 118–136. [CrossRef]
61. Zheng, W.; Yang, W.; Guo, L.; Wang, R. Analysis of Carbon Emission Characteristics and Influencing Factors of Cement Industry in Hebei Province. *Buildings* **2025**, *15*, 1808. [CrossRef]
62. Jing, Z.; Liu, Z.; Wang, T.; Zhang, X. The impact of environmental regulation on green TFP: A quasi-natural experiment based on China's carbon emissions trading pilot policy. *Energy* **2024**, *306*, 132357. [CrossRef]
63. Su, Y.; Cheng, Z. Has green finance reform promoted green growth in Chinese industry? *Environ. Sci. Pollut. Res.* **2023**, *30*, 63136–63147. [CrossRef] [PubMed]
64. Yang, Z.; Zeng, Q.; Wang, Y. The impact of environmental protection tax on green total factor productivity: China's exceptional approach. *Environ. Dev. Sustain.* **2024**. [CrossRef]
65. Qiu, S.; Wang, Z.; Liu, S. The policy outcomes of low-carbon city construction on urban green development: Evidence from a quasi-natural experiment conducted in China. *Sustain. Cities Soc.* **2021**, *66*, 102699. [CrossRef]
66. Shao, W. How the carbon emissions trading system affects green total factor productivity? A quasi-natural experiment from 281 Chinese cities. *Front. Energy Res.* **2023**, *10*, 895539. [CrossRef]
67. Zhang, W.; Zhang, J.; Cheng, Z.; Xu, X. Asset injection, pyramid equity structure and corporate performance under government intervention-Empirical evidence from asset injection of local state-controlled listed companies in China. *Account. Res.* **2015**, *3*, 42–49.
68. Wang, X.; Yu, J.; Fan, G. *Marketization Index of China's Provinces 2016*; Social Science Academic Press: Beijing, China, 2017.