

Article

Does Environmental Inspection Led by the Central Government Improve the Air Quality in China? The Moderating Role of Public Engagement

Fang Xu ¹, Meng Tian ^{2,*} , Jie Yang ² and Guohu Xu ²¹ School of Management, South-Central University for Nationalities, Wuhan 430074, China; xffx2001@126.com² School of Business Administration, Zhongnan University of Economics and Law, Wuhan 430073, China; yj103700@163.com (J.Y.); xgh@zuel.edu.cn (G.X.)

* Correspondence: tianmeng0430@163.com; Tel.: +86-131-6323-1106

Received: 25 March 2020; Accepted: 17 April 2020; Published: 19 April 2020



Abstract: The severe air pollution in China has imperiled public health and resulted in substantial economic loss. To tackle the unprecedented pollution challenges, China has launched a campaign-based environmental inspection over all regions to impel local governments' actual pollution abatement. At the same time, with the public's awakening awareness about environmental protection, the public has also played a particularly vital role in this inspection. Under this circumstance, the study tries to reveal the impact of Environmental Inspection led by the Central Government (EICG) on air quality improvement, and to examine the role of public engagement in their relationship. Specifically, utilizing daily data covering 249 prefecture-level cities in China from 1 June 2015 to 31 May 2018, this study employed multiple regression models and then found that due to the implementation of EICG, the concentrations of PM_{2.5}, PM₁₀, SO₂ and NO₂ decline by 2.642 µg/m³, 6.088 µg/m³, 1.357 µg/m³ and 1.443 µg/m³, respectively, and the air quality index decreases by 2.4 in total, which implies that EICG can improve the air quality to a great extent. However, the coefficients for major variables change from negative to positive, suggesting that an attenuation effect of EICG on air quality improvement exists in Chinese institutional background. Meanwhile, public engagement is shown to enhance the positive association between EICG and air quality improvement. Additionally, further analysis demonstrates that EICG promotes the improvement in air quality up to three months after the inspection in cities during the heating period, while the positive effect has existed during one month before the inspection in cities during the non-heating period. Additionally, in contrast to the instant effect in cities not specially monitored, there is a lagged effect of EICG in controlling the air pollution in cities specially monitored.

Keywords: environmental inspection led by central government; air quality improvement; attenuation effect; public engagement

1. Introduction

China has witnessed enormous economic growth over the past few decades, with an annual growth rate of almost 10% in terms of Gross Domestic Product (GDP) [1]. However, the rapid economic development has also exacerbated the air pollution problem. Despite noticeable improvements in air quality due to a series of emission control measures employed by Chinese governments, many Chinese cities still suffer from various air pollutants, mainly including PM_{2.5} (fine particles smaller than 2.5 µm), PM₁₀ (particulate matter smaller than 10 µm), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbonic oxide (CO) and ozone (O₃). It has been reported [2] that in 2018, 64.2% of the prefecture-level cities in China did not reach the ambient air quality standards set out by the World Health Organization (WHO)

for “good health”. As released in the Environmental Performance Index (EPI) report [3], China’s EPI score only ranked 120th among 180 countries in 2016, of which the air pollution indicator targeted PM_{2.5} concentration even ranked 177th. These severe situations inevitably give rise to tremendous public health burdens, increasing the frequency of respiratory and cardiovascular diseases [4]. What is worse, serious air pollution is highly associated with the risk of premature death. In fact, it is estimated [5] that it has caused 1.6 million deaths in China, accounting for 15.9% of total deaths in 2016. By further estimating with cost-of-illness valuation, the OECD [6] held that Chinese annual economic loss induced by air pollution could be up to approximately 1.4 trillion, as much as 1.9% of China’s GDP.

The severe air pollution has triggered the whole society’s concern in China. In order to address this problem, the Chinese central government has adopted various regulatory measures like revising the Air Pollution Prevention and Control Law, enacting the National Ambient Air Quality Standards and releasing the Three-Year Action Plan to Win the Blue Sky Defense War. In the Chinese “top-down” regulation structure, the central government possesses supreme authority over regulation enactment, while local governments undertake specific enforcement responsibilities; this forms the mainstream political arrangement of environmental decentralization [7]. However, due to the complexity and externality of air pollution governance, local governments have weaker incentives to proactively assume the governance tasks. At the same time, limited by interjurisdictional competition and a severe lack of financial resources, local governments and their officials are inclined to foster sustained economic development at the cost of local air quality and public health [8]. Therefore, weak enforcement towards those top-down air regulation measures in their jurisdictions has thus become a growing phenomenon [9]. For this reason, although consistent attempts have been made by the central government to curb air pollution, the air quality level seems to remain far from WHO guidelines and does not yet reach the public expectation.

Confronted with the enormous pressure related to impelling local governments to actually implement regulatory responsibilities, the central government has increasingly recognized that it is immediately necessary to launch an all-sided environmental inspection over all regions. In this case, the Environmental Inspection led by the Central Government (EICG), as a campaign-based regulatory instrument, has been initiated in 2016. Differently from previous environmental regulatory measures that only supervise over firms’ environmental violations, EICG focuses on discovering local governments’ deviation behaviors like selective execution, perfunctory execution and symbolic execution, and then imposes pressure on them to fulfill their enforcement responsibilities [10]. As a response, local governments are likely to strengthen the regulations enforcement, such as shutting down heavily polluting plants and requiring enterprises to stop production or eliminate outdated equipment, all of which may be effective in controlling local air pollutant emissions.

Given the worsening air pollution and widespread public concern, various in-depth researches on the influence of environmental regulation on air pollution have been conducted [11,12]. However, there is still no consensus on their relations. Most scholars hold the view that strict environmental regulation is conducive to reducing pollutant emissions and substantially improving air quality [13], while some scholars support an inverse U-shaped relationship between environmental regulation and air quality, with the significant sign shifting from positive to negative [14]. The inconsistent results give rise to a number of subsequent studies on the variance in the effectiveness of specific regulatory instruments like environmental legislations, environmental levies and violation penalties [15–17]. However, the remaining problem is that those studies focus mainly on measures targeted at restraining enterprises’ pollution behaviors, with little discussion devoted to regulatory instruments conducted to prompt local governments’ environmental enforcement. Given that the actual regulatory implementation can decide the achievement of regulatory targets to a large part [18], it is of great significance to further explore the regulation effectiveness from the perspective of regulatory enforcement. Under this circumstance, the EICG, as a new regulatory instrument targeted at strengthening local implementation of environmental governance, provides a valuable opportunity to examine its pollution governance

effect, which is a compensation for the inadequate studies on the role of local regulatory enforcement in reducing pollution.

More notably, distinctly from a traditional government-dominating pollution governance structure, EICG further strengthens the role of public engagement in reducing pollutant emissions and conserving energy. This is in accord with the preceding announcements about public engagement in the report to the 19th National Congress of the Communist Party of China, which proposed an overall structure of environmental governance underlining the complementary roles of government, business and the public. Public engagement, as a typical informal regulation [19], plays its particularly vital role in pollution governance. On the one hand, the vast majority of dwellers are directly exposed to high levels of air pollution. Their risk perceptions and high sensitivities towards air pollution motivate them to urge governments and enterprises to take more initiatives in pollution governance [20]. On the other hand, due to the conflicting interests and asymmetric information in the central–local government relation, the formal regulations derived from central government often fail to be effectively implemented by local governments [21]. The public, as an independent third-party force, can restrain local authority, provide pollution clues and alleviate the information asymmetry between central and local governments, which ultimately promote the efficiency of pollution governance in local areas [22].

Many prior studies were concerned with the public's motivations and approaches to participate in pollution governance [23], as well as their interactions with local governments [24]. As for the outcomes of public engagement in pollution governance, further studies have also been undertaken to summarize its influence on air pollution, using different methods such as case reviews [25], in-depth interviews [26] and quasi-experimental designs [27]. However, scarce research has addressed this impact using a large-scale municipal dataset and econometric model. In addition, although the direct implication of public engagement on pollution governance has been concerned, very little research has incorporated EICG and public engagement into a uniform analysis framework to explicate the intricate influences of formal and informal regulations on air quality improvement.

To address the aforementioned gaps, we endeavor to reveal the effect of EICG, a campaign-based regulatory program, on Chinese air quality improvement, and the role of public engagement in their relationship in the current study. Using daily data covering 249 prefecture-level cities of China from 2015 to 2018, the current study employed multiple regression models to examine whether EICG reduces various single pollutant indexes such as $PM_{2.5}$, PM_{10} , SO_2 , NO_2 , CO and O_3 and the composite pollution index like the Air Quality Index (AQI), as well as whether there is a moderating role of public engagement.

Some of the study's advantages over prior researches may deserve to be acknowledged here. First, although prior literature has investigated the air pollution governance effects of Chinese various regulatory instruments, like the New Ambient Air Quality Standards and Ten Air Pollution Prevention and Control Measures, these instruments primarily contribute to setting out the expected regulatory goals and subsequent action plans. However, limited attention has been paid to whether and how EICG, aiming at ensuring regulations enforcement, affects air pollution governance, which is the specific target of this study. Second, this study provides further evidence for a significant variance between the short-term and long-term effects of EICG on air quality, which remains rarely explored in existing studies. Third, this study examines the joint influences of EICG and public engagement on air quality improvement, which helps fill the gap that the meaningful role of public engagement in facilitating regulation effectiveness is neglected in existing studies. Finally, the heterogeneous factors like heating period and specially monitored regions are also incorporated, so as to provide a further understanding for environmental regulators about the enforcement of EICG in the Chinese institutional environment.

The remaining sections of the paper are arranged as follows. Section 2 introduces EICG's institution background. The hypotheses are proposed in the following section. Section 4 reports the sample, variables and models used in the paper. Section 5 provides empirical results and discusses the

explanations. Finally, Section 6 contains conclusions and provides relevant contributions, limitations and future research opportunities.

2. Institution Background of EICG

Owing to the increasing air pollution, the central government in China has implemented a wide array of regulations, such as enacting the Air Pollution Prevention and Control Law and releasing the New Ambient Air Quality Standards to resolve this issue. Nevertheless, the air quality is still poor and the annual limit values for PM_{2.5} and PM₁₀ concentrations are widely exceeded across China. In 2017, 74.2% of heavily polluted days were primarily induced by PM_{2.5} and 20.4% were induced by PM₁₀ [28]. The continuous severe air pollution implies that these regulatory instruments may not play their roles as expected to some extent. This regulatory inefficiency may stem from the “top-bottom” Chinese traditional environmental regulation structure [29]. That is, Chinese central government, as the principal, holds absolute power over establishing regulations, setting goals and evaluating performance, while the local governments, as the agents, are responsible for the implementation of top-down regulatory instruments [30]. This so-called principal–agent relation could easily give rise to the weakness of local environmental regulation enforcement. Driven by the information asymmetry arising from the principal–agent relation, together with the bounded rationality, local officials are likely to adjust the actual implementation for regulations enacted by the central government [9]. Even worse, they may be inclined to take collusive actions with their subordinate officials and local polluting firms. In this case, a variety of exaggerated behaviors, like environmental performance information fraud and goal displacement, exist in the actual regulation implementation of local governments. Furthermore, the political competitions among various local governments may also result in a “race to the bottom” in air pollution governance rather than a “race to the top” [31]. To obtain a greater economic achievement in a short time, some local governments tend to deregulate the polluting industry, and at the same time attract more capital investment at the cost of air quality [32]. The ineffective regulation enforcement undoubtedly leads local areas, especially those economically undeveloped areas, to be a pollution haven in which the air quality continues to deteriorate.

To enhance the efficiency of local environmental enforcement, on 1 July 2015, Chinese central government promulgated the Environmental Protection Inspection Scheme (EPIS), which ascertains a comprehensive inspection mechanism from the perspective of top-level design. According to the instruction of EPIS, the central government therewith launched a national-level inspection of each province. Inspection teams have been dispatched to supervise over local pollution governance, especially in those areas with serious air pollution issues, frequent environmental events or weak environmental enforcement. Since the initiating of the inspection mechanism in 2016, the Environmental Inspection led by the Central Government (EICG) has been widely regarded as a significant institutional arrangement for strengthening environmental protection and constructing an ecological civilization, as well as revolutionizing the conventional environmental supervision system.

In January 2016, the EICG team initiated the pilot inspection in Hebei province, which kicked off the national-level inspection of all provinces. During the inspection period of one month, the EICG teams complied with several strict procedures. Firstly, inspectors obtained pollution clues from the public via various complaint channels including telephone hotlines and mailboxes. Based on a great deal of complaint information, they made a preliminary judgment about local environmental governance. Secondly, through reviewing the documentary files and interviewing local regulators and other relevant personals, as well as conducting field investigations, inspectors further verified these pollution clues and sorted them into various kinds of problem lists. Specific to the exigent pollution problems encountered during the inspection, inspectors would instantaneously interview those responsible officials and oblige them to make detailed statements for the major causes of the problems. Thirdly, a comprehensive inspection report was generated by inspectors and was subsequently handed to local governments for rectification within a specified deadline. Finally, when local governments completed the rectification tasks and submitted their rectification schemes to the State Council, inspectors would

verify the rectification implementation in order to inhibit selective rectification, perfunctory rectification or symbolic rectification.

During the period of environmental inspection, inspection teams have adopted diversified administrative actions, ranging from conducting targeted inspection over local polluting firms to strengthening responsibility-tracing mechanism for local officials. Numerous severe problems, such as continuous pollutants discharge beyond pollution limits from polluting firms, inactive actions adopted by local governments and even collusive behaviors between firms and governments, have also been disclosed in this nationwide campaign to fight pollution. At the end of the inspection of all provinces in September 2017, the inspection teams received more than 135,000 public complaints, resulting in the punishment of 29,000 cases and a cumulative penalty of about 1.43 billion RMB [33]. In addition, 1527 people were detained, 18,448 people were interviewed by inspectors, and 18,199 local officials have been held accountable for pollution events and 2230 rectification tasks in total were handed to local governments [33].

According to the rectification schemes disclosed to the public, several important dimensions of air pollution are noteworthy. First, an excessive level of pollutant concentration, serious seasonal air pollution and downward ranking in air quality were especially pronounced during the inspection. Second, the EICG focuses more on the abatement of PM_{2.5}, PM₁₀, SO₂ and NO₂ pollution to which the general public is highly sensitive, while giving insufficient attention to other atmospheric composition like CO and O₃. Finally, in response to the air pollution rectification requirements, the majority of local governments center on controlling the emissions from pollutant sources, mainly including industrial waste gases, fossil fuel combustion and industrial dust.

Through this campaign-based inspection, a number of rectification tasks have been fulfilled by local governments in succession, which indicates the effectiveness of EICG in promoting local environmental enforcement to some extent. The critical dimensions leading to the effectiveness are twofold: national authority and public engagement. On the one hand, although a range of environmental regulatory instruments have been enacted by Chinese central government to cope with the pollution problems, the deviation behaviors of local governments during their enforcements are especially pronounced. To address this issue, since the initiating of inspection, the EICG teams are endowed with the highest level of national authority, directly accountable to the State Council. Resorting to the political interference of national authority, the EICG can compel local governments and their officials at all levels to abandon the deviation behaviors and pay sufficient attention to local pollution governance.

On the other hand, with the increasing awareness of pollution governance, the public has actively engaged in the process of environmental inspection. As practitioners, they resort to their familiarities with surrounding emission sources to provide local knowledge and practical experience to inspection teams, which is conducive to discovering valuable pollution clues. As supervisors, they not only monitor whether polluting firms have fulfilled their environmental responsibilities, such as abandoning the heavy-polluting projects, avoiding predatory exploitation for natural resources and utilizing clean energy during the production, but also supervise whether local governments have actually implemented the regulatory instruments set by the central government. Once the public detects any environmental violation event surrounded them, they can deliver their direct appeals to the inspection teams or environmental sectors through various channels. According to the data released by the Ministry of Ecology and Environment (MEE), in 2017 the MEE has received 170,000 complaints from the public via its website and mobile platform, 3.5 times higher than that in 2014. In addition, EICG teams have also received 135,000 public complaints during the inspection. In this regard, the fact that the public plays a prominent role during this inspection can never be neglected.

3. Hypothesis Development

3.1. Impact of EICG on Air Quality Improvement

It is widely accepted that air pollutants severely threaten human health, as well as having an adverse effect on sustainable economic development [34]. Therefore, air pollution abatement has become a priority task for the governments of both developed and developing countries. Numerous environmental regulatory instruments have been put into practice by environmental sectors. Specifically, environmental regulations, deemed as a full range of legitimate instruments designed to reduce the externality of environmental pollution [35], are generally divided into two types: command-and-control regulations and market-incentive ones [36]. The former involve the legislations, rules and standards that stipulate the ceilings or limits of pollution emissions. In Chinese practice, various compulsory regulations, like the Cleaner Production Promotion Law and the Circular Economy Promotion Law, have also clarified the punishments on polluting behaviors. The latter refers to the economic instruments that employ market signals to encourage pollution reduction behaviors. The most popular forms of market-incentive regulations incorporate carbon dioxide (CO₂) taxes, pollution control subsidies and tradable emission permit systems. Compared with these non-compulsive regulations, command-and-control regulations, resorting to their coercive powers, still play a leading role in Chinese regional pollution governance [37].

Considering the significance of environmental regulations, numerous researchers have paid sufficient attention to their impacts on air pollution abatement in different contexts. Some researchers hold that well-designed environmental regulations can restrain pollution emissions and improve air quality significantly. Based on the UK industry-specific emissions data from 1990 to 1998, Cole et al. [11] found that environmental regulations, both formal and informal, have a positive effects on reducing air pollution intensity, which is the weighted average of concentrations for six pollutants including SO₂, NO_x, acid rain precursors, CO, PM₁₀ and CO₂. Greenstone and Hanna [13] used a difference-in-differences method to assess the roles of India's environmental regulations on air quality improvement. They found that the enactment of Supreme Court Action Plans is associated with large reductions in PM and SO₂, and the popularization of Mandated Catalytic Converters results in a decline in NO₂. In a similar vein, much other literature has also yielded positive results [12,38].

In contrast to these viewpoints, some other scholars argued that strict environmental regulations may have adverse effects on air quality. For instance, using bilateral trade data for 38 European countries, Bagayev and Lochard [39] documented that stringent air quality regulations decreased the concentrations for SO₂, PM₁₀ and NO₂ in developed countries and conversely increased them in less-developed ones through the expansion of bilateral trade activities. Recent studies have further analyzed the causal relationship between environmental regulations and air quality improvement. An inverse U-shaped relationship between them was also raised and confirmed in some empirical studies. For example, employing a panel threshold model, Ouyang et al. [40] found that along with the increase of environmental regulation stringency, PM_{2.5} emission first rises and then shows no significant change, and therewith reduces.

So far, there is still no unified conclusion on the impact of environmental regulations on air quality improvement. In fact, the effectiveness of environmental regulations depends largely on the existing institutional framework. Some institutional factors, such as marketization degree [41], ownership structure [42] and government enforcement [43], have been emphasized as essential determinants influencing the regulatory effects. Under the special institution arrangement in China, which advocates decentralization as a mainstream political regime, local government enforcement seems particularly essential in promoting regulatory success. Previous studies have also confirmed that strengthening inspection and punishment can rectify local governments' deviation behaviors and enhance their environmental responsibility fulfillment, thus ensuring the regulatory effectiveness [44].

In China, EICG, deemed as a necessary complement for the existing regulatory instruments [45], aims at monitoring local governments to implement necessary actions to control pollution and thus

improve environmental quality under their jurisdiction. In the past, localization management in the domain of pollution governance has enabled local governments to evade the implementation responsibilities assigned to them [46]. To maximize their advantages for promotion, local officials were inclined to provide special protection for local polluting firms that contribute greatly to local economic growth. Even when they have noticed the official information about the national-level inspection, they probably continued preceding behaviors like selective execution, perfunctory execution and symbolic execution to handle the inspection pressure in advance [47].

When inspection teams were dispatched to local areas, inspectors would directly concern themselves with the significant air pollution issues that cause widespread public resentment. The problem that the concentrations of $PM_{2.5}$ and PM_{10} exceed permissible standards was given especially high priority because these two pollutants are closely related to human health [48]. On account of the specific national authority endowed by the State Council, the inspection teams can resort to the deterrent force to impose political pressure on local governments and urge their actual implementation for regulatory measures. Targeting the violation behaviors from heavy-polluting firms discovered in the inspection, such as discharging pollutant emissions beyond pollution limits and authorizing unqualified environmental impact assessment, inspection teams would require local governments to ascertain the administrative penalty intensity in accordance with the pollution level. At the same time, under the high pressure of EICG, some projects with heavy polluting and high energy consumption were also urged to be abolished and the backward production facilities were demanded to be eliminated by local governments, all of which are conducive to restraining the high air pollution in a timely manner.

Furthermore, EICG has shifted its focus from “supervising polluting firms” to “supervising local governments” [49]. Since the initiation of EICG, a strict accountability mechanism targeting local officials has been put into practice, which greatly rectifies the phenomenon of the “race to the bottom”. That is, local officials are likely to no longer conspire with local polluting firms, but instead make great efforts to compel firms to reduce pollution discharge and ensure environmental compliance. In addition, differently from previous GDP-dominated performance evaluation methods for official promotion, the Chinese central government established a complementary evaluation system that takes the EICG report as an important criterion to audit the environmental accountability for the officials who would be promoted. Therefore, the inspection report and rectification evaluation submitted to the State Council have generated a deterrent force to local governments and their officials, especially for some officials who failed to fulfill their responsibilities in the pollution governance and who are likely to lose their chances of political promotion and even be prosecuted. In this regard, local governments and their officials may abandon preceding deviation behaviors and actively accomplish the rectification tasks, in an effort to respond to the political pressure arising from EICG endowed with the national authority. Their initiative actions are more beneficial to control local pollutant emissions and improve air quality. Thus, the following is hypothesized:

Hypothesis 1. *EICG has a positive effect on air quality improvement in China.*

Traditionally, the regulatory capacity decreases with the downward shift of government hierarchy, leading to a dilemma in regulations enforcement [50]. Differently from conventional environmental regulations, EICG exhibits a distinct feature of campaign-based governance. The EICG, relying on the national power, rapidly breaks through the routine hierarchical governance structure and delivers the signals of comprehensively curbing pollution to local governments at all levels in a short time [49]. Through integrating the human resources, physical resources and administrative resources with the authorization of the State Council, EICG teams can review all environment-related profiles in detail, instantly interview all relevant persons, including the governor and secretary of a provincial committee of the Communist Party of China, and conduct unobstructed field investigations. The all-around inspection is conducive to effectively prohibiting the administrative negligent behaviors and rapidly discovering the pollution sources and thus requiring rectification.

However, although the campaign-based supervision can transfer high pressure to local governments and help reach the expected goals rapidly, this pressure may exert a trend of apparent attenuation as the end of the inspection, and the deterrent power of EICG is thus likely to be weakened. The attenuation effect has occurred in similar contexts like Chinese land supervision over the past few years [51]. Several land problems, such as unreasonable approval procedures and inadequate rectification, have been found and resolved through all-around powerful inspections. However, with the completion of this campaign-based inspection, those problems addressed before have reoccurred over time [51].

In a similar vein, there may still be difficulties in maintaining the sustainable effect of EICG on air pollution abatement. On the one hand, the EICG is prone to be recognized as a temporary environmental regulation, which gives rise to local polluting firms' speculative behaviors or inspection risk aversion behaviors. Specifically, in order to avoid spending substantial cost in updating facilities and transforming operation models, the business executives are likely to shut down their plants and stop production or temporarily make their purification treatment facilities work during the one-month inspection. Once the inspection has finished, they can resume the previous production modes immediately. In this case, local pollution emissions from these firms can still not be under effective control over a long period. That is, the effect of a short-term inspection may be limited in controlling long-term pollution.

On the other hand, the temporary inspection enables some local governments to implement the "one size fits all" mode, which implies that they may take the uniform measures of stopping production for all polluting firms even if some firms discharge pollutants under the national standards for pollution emissions. This rough governance mode can help local governments quickly achieve a temporary effect of air pollution abatement, which results in a similar phenomenon to the so-called "APEC blue" [52]. That is, although Beijing's air quality was excellent during the Asia-Pacific Economic Cooperation (APEC) Meeting held in the city from 7 to 12 November 2014 owing to the ultra-convention and campaign-based regulatory measures implemented by the local government, a rebound phenomenon of air pollution subsequently occurred with the end of this meeting.

In addition, after the inspection, considering the local long-term development in the jurisdiction charged by local officials, they may still deregulate local polluting firms to boost economic growth and to promote employment, both of which weigh higher than ecological governance targets in the whole administrative assessment system. Under this circumstance, local polluting firms are likely to dramatically increase production with the completion of the inspection in order to offset the preceding economic loss induced by production restriction due to the EICG. In summary, the heavy-polluting firms' speculative behaviors during the inspection and their subsequently compensating production after the inspection, together with local governments' misunderstanding of the EICG's long-term importance, may result in an attenuation effect of the EICG. Thus, we put forward the following hypothesis:

Hypothesis 2. *The impact of EICG on air quality improvement is weakened over a longer time.*

3.2. The Moderating Role of Public Engagement

Public engagement is commonly defined as the degree to which citizens are conscious of puzzles in public affairs and make their efforts to provide solutions [53]. Air pollution, as a primary hazard to human health, has attracted an increasing level of public concern and engagement worldwide [54]. On account of the public's significant role in pollution governance, the Chinese government vigorously encourages them to participate in the campaign against pollution. Generally, the public actively gets involved in air pollution governance primarily based on two categories of driving impetus. The internal impetus stems from the public's increasing concerns about the adverse effect of air pollution on citizens' rights of health, property security and comfortable working environment [55]. The external impetus usually derives from their growing discontentment with the ineffectiveness of formal environmental regulations [56]. Under the decentralized systems in China, given that the environmental information

disclosed by local governments is inclined to be distorted, together with the absence of a routine supervision mechanism, the governance results of formal regulations remain far from adequate and effective [57]. Under these circumstances, the public, as a third-party force besides governments and enterprises, can play their imperative roles in controlling air pollution and improving air quality.

Generally, the public engages in pollution governance through several approaches. First, as one of the major energy consumers and pollution emitters, the public affords their direct responsibilities through initiative actions of environmental protection like garbage sorting, low-carbon transportation and green consumption [58]. Second, the public delivers environmental appeals to governments and influences their decision-making. Especially when an environmental policy is about to be formulated, the public can express their accumulated experience in practice through participating in environmental hearings [59]. Finally, the public resorts to environmental supervision to further prompt local pollution governance [60]. The public's interventions in several domains, including regulation enforcement, environmental impact assessment, corporate environmental responsibility fulfillment and environmental violation exposure, not only maintain their own ecological rights, but also effectively compensate for the lack of formal regulatory capacity.

With the continued engagement of the public in pollution abatement, the positive influence of public engagement on air quality improvement has emerged and has thus been paid much attention by governments and scholars. Using a simultaneous equation model based on a sample of 404 industrial factories in Brazil, Feres and Reynaud [61] found that local community pressure can compel polluters to implement corrective actions, and thus leads to the reduction of SO₂ emission. Employing data covering 109 prefecture-level cities in China, Zhang et al. [62] documented that public opinion contributes to reducing the concentrations of two main air pollutants—PM_{2.5} and PM₁₀. Based upon the Data Envelopment Analysis (DEA) model, Liu et al. [63] found that public engagement can significantly enhance the pollution emission efficiency in the areas with unsustainable development.

Although the formal regulations initiated by governments still maintain a dominant role in pollution governance under the current institutional background in China [37], public engagement, as an informal regulation, plays a particularly vital part in the formal regulatory implementation. Given that, scholars have begun to focus on the role of public engagement in the pollution governance effect of formal environmental regulations. Utilizing national survey data concerning the public's environmental satisfaction, Tang et al. [64] found that the public's dissatisfaction with the surrounding environment can stimulate local governments to invest more in pollution governance, especially in controlling waste gas pollution. Based on the evolutionary game model analysis, Chen et al. [65] argued that the public's interaction with governments can promote the governance effect of three industrial wastes, including waste gas, waste water and solid waste.

In a similar vein, during the period of this national-level inspection, public engagement has also become a core element in promoting the governance effect of EICG. Compared with water pollution and solid waste pollution, air pollution poses a more direct health risk over a long time and thus leads to a high sensitivity of the public. Thus, the public would concern itself more with related topics such as severe haze. We can understand the role of public engagement in EICG's air pollution governance effect from the perspectives of the public's roles and inspection process. From the perspective of the public's roles in air pollution governance, the public, as pro-environmental actors, can utilize their greater environmental knowledge to conduct pro-environment behaviors like implementing garbage classification, saving electrical energy and using clean fuels in daily life, which undoubtedly promotes the improvement of environmental quality [66]. As information providers, the public can deliver more detailed pollution information from their surroundings to inspection teams in a timely manner since the initiating of EICG. According to the viewpoint of Alonso et al. [67], the "information alliance" between the public and inspectors can mitigate the problem of central–local government information asymmetry to a large extent. Relying on the information provided by the public, the inspection teams can collect violation clues rapidly, identify the pollution sources precisely and evaluate the rectification effect accurately. As an informal supervisor, the public can help inspectors restrain local governments'

preference behaviors and even their collusion with local polluting firms, as well as thus helping reduce the administrative cost of EICG initiation, all of which are conducive to ensuring the pollution abatement effect of EICG.

From the perspective of the inspection process, in the initiation stage, the public complains about local environmental violation events to EICG teams through 24/7 complaint channels, so as to help inspectors integrate pollution clues. In the further investigation stage, the public assists inspectors to identify the pollution problems accurately and formulate the rectification tasks to local polluting firms and governments. Even during the rectification phase, the public can still supervise over local governments' consequential behaviors, including setting rectification targets, formulating rectification schedules, implementing rectification tasks and ensuring rectification persistence. In summary, the public engagement during the inspection can impose increasing pressure on local governments and firms and compel them to take effective regulatory actions to reduce local pollution and enhance air quality. Conversely, without a high level of public engagement, the influence of EICG on pollution governance may be greatly reduced. To this end, the following is hypothesized:

Hypothesis 3. *Public engagement plays a significantly moderating role in the relationship between EICG and air quality improvement in China.*

4. Methodology

4.1. Variables and Data Sources

Given that EICG lasted for almost two years from 2016 to 2017 and has covered all provinces in Mainland China, we firstly selected all prefecture-level cities in the Chinese Mainland as the original samples. As for the time period of the data for this study, we chose to use three-year daily data from 1 June 2015 to 31 May 2018, which is conducive to further examining whether there is an attenuation effect of EICG on air quality improvement. After further filtering out some cities with missing data, we utilized 249 prefecture-level cities with daily data as the final samples in this paper.

To investigate the impact of EICG on air quality improvement, several air pollutant indexes were used as the dependent variables in multiple regression models. Specifically speaking, six single pollutant indexes including $PM_{2.5}$, PM_{10} , SO_2 , NO_2 , CO and O_3 were utilized to reflect the effect of EICG on a specific atmospheric composition. The air quality index (AQI), formulated through standardizing these single pollutant indexes, was also incorporated to further examine the influence of EICG on overall air quality. In addition, the overall pollution level (OPL), ranging from excellent to severe, enables the public to have an intuitive sense of air quality and thus was introduced as a substitute variable to AQI used for robustness check in the regression models. The data of these air indexes were collected from the air quality real-time publishing platform (<http://106.37.208.233:20035/>), which was established and is operated by the Chinese National Environment Monitoring Station. As for the independent variable, EICG, deemed as a dummy variable, it reveals whether an EICG team is inspecting a specific province to which a sample city belongs on a day from 1 June 2015 to 31 May 2018. According to the arrangement deployed by the central government, the EICG teams are required to implement a one-month inspection in each province. That is, the variable of EICG equals 1 if the province is at a point of being inspected, and 0 otherwise.

Public engagement is the core moderating variable considered in this study. To our knowledge, it is difficult to measure public engagement directly. Generally, most scholars utilize proxy indicators such as the numbers of media reports [62] or the quantity of complaint letters and calls during a certain period [68] to measure it. However, these indicators mainly reflect that the public passively participates in the pollution governance affairs when confronting with severe pollution surrounding them, rather than considering the public's initiative efforts to contribute to pollution abatement. At the same time, the data for these indicators are collected from traditional media channels, rather than from the new media like social networks and search engines, which are the current mainstream platforms

being utilized by the public to obtain information and express appeals. For these reasons, in this study, we applied a Baidu search index to measure public engagement. On the one hand, the public obtains information related to environmental inspection by initiatively searching the Internet, and formulate their knowledge and attitudes about this inspection. According to the viewpoint of Oltra et al. [69], the public's attention to this specific issue is conducive to arousing their enthusiasm to participate in the whole inspection process and thus helping control air pollution. Therefore, the public's Internet searching behaviors can reflect their engagement behaviors in this inspection to some extent. On the other hand, the mass daily data about the specific topic of environmental inspection obtained from the Baidu search engine overcomes the limitation of lack of daily data, which exists in the above-mentioned methods used to measure public engagement, and thus helps to resolve the endogenous problem effectively [70]. Therefore, the daily search volume of the public about a specific word about the environment can be a good substitute for public engagement [71]. Utilizing the search index of Baidu (<http://index.baidu.com>), which occupies more than 80% of Chinese search market and thus is more appropriate to reflect Chinese public engagement than Google and other search engines, we retrieved the public's daily search volume of "environmental inspection" in 249 prefecture-level cities, from 1 June 2015 to 31 May 2018, as a proxy for public engagement, to further examine its influence on the relationship between EICG and air quality improvement.

To ensure the accuracy of the empirical results, we also considered several control variables in our study. Concerning the heterogeneous influences of time-related factors on air quality [72], we firstly introduced month, week, weekday and holiday as control variables. The data related to these time variables were collected from the calendar query platform (<http://www.365rili.com/>). In addition, considering that weather conditions also have significant impacts on air quality [62], we also incorporated factors related to weather in the regression models to control for their effects on air quality improvement. Specifically, windy, rainy or snowy days as key factors influencing the air quality have also been introduced as control variables in the current study. At the same time, in view of the possible influences of maximum and minimum temperatures in a day on air quality, we also controlled for them. The data of these weather conditions were obtained from the China Weather platform (<http://www.weather.com.cn>), which was established and is managed by the China Meteorological Administration (CMA). In order to control the inherent differentiation among all sample cities in different years, we also introduced year and city as dummy control variables. To sum up, Table 1 presents the definitions of the variables employed in this study. The daily data for these variables were collected from 1 June 2015 to 31 May 2018.

Table 1. Variables definition.

Variables	Unit	Definition
PM _{2.5} (PM _{2.5})	µg/m ³	A city's PM _{2.5} concentration in each day.
PM ₁₀ (PM ₁₀)	µg/m ³	A city's PM ₁₀ concentration in each day.
SO ₂ (SO ₂)	µg/m ³	A city's SO ₂ concentration in each day.
CO (CO)	mg/m ³	A city's CO concentration in each day.
NO ₂ (NO ₂)	µg/m ³	A city's NO ₂ concentration in each day.
O ₃ (O ₃)	µg/m ³	A city's O ₃ concentration in each day.
Air Quality Index (AQI)	µg/m ³	A city's standardized value based on various single pollutant indexes in each day. The higher the value, the worse the air quality.
Overall Pollution Level (OPL)	—	A city's air quality grade in each day; the numbers 1 through 6 correspond to six categories including excellent, good, lightly polluted, moderately polluted, heavily polluted and severely polluted.
Environmental Inspection led by the Central Government (EICG)	—	Dummy variable, when an EICG team is inspecting the province to which a specific city belongs on a day, EICG = 1, otherwise 0.

Table 1. Cont.

Variables	Unit	Definition
Public engagement (PUBEN)	—	Ratio of a city's daily search volume with the keyword of "environmental inspection" to its annual average population.
Month (MONTH)	—	The numbers 1 through 12 correspond to the 12 months in a year.
Week (WEEK)	—	The numbers 1 through 52 correspond to the 52 weeks in a year.
Weekday (WEDA)	—	The numbers 1 through 7 correspond to the 7 days in a week.
Holiday (HOLI)	—	Dummy variable, if the day is a statutory public holiday, HOLI = 1, otherwise 0.
Rain (RAIN)	—	Dummy variable, if the day is a rainy day, RAIN = 1, otherwise 0.
Snow (SNOW)	—	Dummy variable, if the day is a snowy day, SNOW = 1, otherwise 0.
Maximum air temperature (MAXI)	°C	The maximum air temperature record in each day.
Minimum air temperature (MINI)	°C	The minimum air temperature record in each day.
Wind (WIND)	Grade	The wind grade record in each day.

4.2. Model Specification

Based on the above analysis, the following model is specified to verify the impact of EICG on air quality improvement:

$$Y_{it} = \alpha_0 + \alpha_1 EICG_{it} + \alpha_2 X_{it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (1)$$

where the dependent variable Y_{it} measures the air quality, reflected by eight air indexes: PM_{2.5}, PM₁₀, SO₂, NO₂, CO, O₃, AQI and OPL. i and t represent the cities and the time, respectively. X_{it} is the series of control variables mentioned above, μ_i is the city fixed effect, φ_t is the time fixed effect, and ε_{it} acts as a random disturbance term. $EICG_{it}$ is a dummy independent variable. Given that the higher values for these eight air indexes represent the worse air quality, a negative value of the coefficient α_1 indicates that EICG can decrease air pollution, namely improving air quality.

Then, the model for verifying the attenuation impact of EICG on air quality improvement is proposed as Equation (2), and the model for testing the moderating role of public engagement is proposed as Equation (3).

$$Y_{it} = \alpha_0 + \alpha_1 BEFORE1_{it} + \alpha_2 EICG_{it} + \alpha_3 AFTER3_{it} + \alpha_4 AFTER6_{it} + \alpha_5 X_{it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \alpha_0 + \alpha_1 EICG_{it} + \alpha_2 PUBEN_{it} + \alpha_3 EICG * PUBEN_{it} + \alpha_4 X_{it} + \mu_i + \varphi_t + \varepsilon_{it} \quad (3)$$

In Equation (2), $BEFORE1_{it}$, as a dummy variable, stands for the period of a month before an inspection team was dispatched to the province in which a city is located. In the same vein, $AFTER3_{it}$ and $AFTER6_{it}$ represent the period of three months and six months after the inspection, respectively. In Equation (3), $PUBEN_{it}$ is a measure of public engagement in city i at day t , while $EICG * PUBEN_{it}$ is the interaction term of EICG and public engagement, which is utilized to examine the moderating effect of public engagement.

5. Results and Discussion

5.1. Descriptive Statistics

As noted in Table 2, the mean values of Air Quality Index (AQI) and Overall Pollution Level (OPL) are 76.431 and 2, respectively, implying that the average air quality during the sample period was relatively good. By further calculating, we found that 19.2% of the sample days were still in lightly polluted grade or an even worse level. Specifically, the sample days in heavily or severely polluted

level still account for 12.7% of the total polluted days, which implies that it is still worthy to pay special attention to the air quality improvement in sample regions. At the same time, the median value of AQI in these polluted days is 128, which indicates that the air pollution in some cities in specific periods was still severe. The maximum concentration values of some single indicators like $PM_{2.5}$, PM_{10} , SO_2 are $848 \mu g/m^3$, $2119 \mu g/m^3$ and $800 \mu g/m^3$, respectively, all above the WHO recommended maximum level and even more than tenfold this level, also providing evidence for a serious air pollution situation in China.

Table 2. Descriptive statistics of the main variables.

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
$PM_{2.5}$	257,395	47.073	38.440	0	848
PM_{10}	257,395	81.982	60.535	0	2119
SO_2	257,395	20.117	21.781	0	800
CO	257,395	30.534	17.410	1	187
NO_2	257,395	1.012	0.556	0	18.920
O_3	257,395	59.651	29.512	0	255
AQI	257,395	76.431	45.373	9	500
OPL	257,395	2.000	0.926	1	6
RAIN	257,395	0.351	0.477	0	1
SNOW	257,395	0.023	0.151	0	1
MAXI	257,395	20.382	11.006	−41	42
MINI	257,395	11.313	11.516	−43	32
WIND	257,395	3.460	0.732	0	12

5.2. Baseline Results: Effects of EICG on Air Quality Improvement

Table 3 provides the multiple regression results, of which columns (2)–(8) are the relationships between EICG and seven air indexes, while column (9) is the result of the robustness check. The estimated results indicate that the coefficients of EICG are negative at the 0.1% level of significance except for CO and O_3 . Specifically, after controlling for the effects of time, cities and weather conditions, the concentrations of $PM_{2.5}$, PM_{10} , SO_2 and NO_2 decline by $2.642 \mu g/m^3$, $6.088 \mu g/m^3$, $1.357 \mu g/m^3$ and $1.443 \mu g/m^3$ due to the implementation of EICG, respectively, while the AQI decreases by 2.418 induced by EICG. That is, the EICG improves the overall air quality significantly and reduces the concentrations of major pollution components like $PM_{2.5}$, PM_{10} , SO_2 and NO_2 , which support Hypothesis 1 to a large extent. However, it is also worth noting that the coefficient of EICG on O_3 is significantly positive, and the coefficient for CO is positive but not significant, which implies that the implementation of EICG may intensify the CO and O_3 pollution. The differentiated results between CO, O_3 and other air indexes may stem from two aspects. On the one hand, during this inspection, the inspectors mainly took some key pollutants like $PM_{2.5}$ and PM_{10} , with which the public is more concerned, as indicators for evaluating the rectification effect, while insufficient attention was given to the reduction of CO and O_3 , both of which are also difficult to be perceived intuitively by the public, ultimately resulting in local governments' selective abatement on specific pollutants in their rectification practices.

Table 3. Impacts of EICG on air quality improvement.

Variable (1)	PM _{2.5} (2)	PM ₁₀ (3)	SO ₂ (4)	NO ₂ (5)	CO (6)	O ₃ (7)	AQI (8)	OPL (9)
EICG	−2.642 *** 0	−6.088 *** 0	−1.357 *** 0	−1.443 *** 0	0.005 −0.34	0.563 * −0.033	−2.418 *** 0	−0.053 *** 0
MONTH	2.116 *** 0	5.162 *** 0	0.657 *** 0	1.040 *** 0	0.031 *** 0	−4.184 *** 0	2.357 *** 0	0.040 *** 0
WEEK	−0.447 *** 0	−1.144 *** 0	−0.172 *** 0	−0.097 *** 0	−0.006 *** 0	0.601 *** 0	−0.554 *** 0	−0.009 *** 0
WEDA	−0.579 *** 0	−0.493 *** 0	−0.146 *** 0	0.202 *** 0	−0.006 *** 0	−0.131 *** 0	−0.426 *** 0	−0.008 *** 0
HOLI	3.565 *** 0	3.580 *** 0	0.791 *** 0	−1.135 *** 0	0.024 *** 0	0.312* −0.014	3.408 *** 0	0.070 *** 0
RAIN	−2.730 *** 0	−6.594 *** 0	−1.879 *** 0	−0.204 ** −0.001	0.013 *** 0	−8.714 *** 0	−5.755 *** 0	−0.132 *** 0
SNOW	4.110 *** 0	0.608 −0.379	2.157 *** 0	−1.740 *** 0	0.01 −0.106	5.880 *** 0	4.690 *** 0	0.100 *** 0
MAXI	0.738 *** 0	2.862 *** 0	0.502 *** 0	0.680 *** 0	0 −0.889	2.015 *** 0	1.724 *** 0	0.039 *** 0
MINI	−2.017 *** 0	−4.268 *** 0	−1.219 *** 0	−1.298 *** 0	−0.018 *** 0	−0.298 *** 0	−2.833 *** 0	−0.060 *** 0
WIND	−5.738 *** 0	−1.385 *** 0	−3.051 *** 0	−4.497 *** 0	−0.093 *** 0	3.338 *** 0	−3.586 *** 0	−0.077 *** 0
Constant	92.222 *** 0	82.444 *** 0	40.405 *** 0	48.513 *** 0	1.371 *** 0	18.670 *** 0	99.848 *** 0	2.466 *** 0
YEAR DUM	YES	YES	YES	YES	YES	YES	YES	YES
CITY DUM	YES	YES	YES	YES	YES	YES	YES	YES
Adj. R *	0.2822	0.3097	0.4331	0.499	0.3963	0.4398	0.2929	0.2904
F value	404.22 ***	461.09 ***	784.60 ***	1022.39 ***	674.19 ***	806.02 ***	425.69 ***	420.62 ***
OBS	257,395	257,395	257,395	257,395	257,395	257,395	257,395	257,395

Note: ***, ** and * refer to $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively. OBS: observation.

On the other hand, PM_{2.5} and PM₁₀, as two compound pollutants, usually result from the chemical reaction process of different gaseous pollutants including SO₂ and NO_x, as well as smoke and dust particles, almost all of which are emitted from industrial sources like coal-fired plants, the chemical industry and steel enterprises [73]. Correspondingly, local governments can formulate the rectification schemes targeting these pollution sources, including eliminating coal-fired boilers, introducing the “convert oil to gas” practice and reconstructing desulfurization and denitration facilities, which directly contribute to reducing these pollutants. However, CO, formulated under the incomplete combustion of carbon-containing fuels, is insoluble in water and thus difficult to be broken down [74]. At the same time, the elimination of CO can be achieved mainly through the reaction with the free radical of HO in the air. However, the implementation of EICG can improve the air quality, giving rise to a decreased concentration of the free radical, which is thus adverse to decreasing the CO concentration. Furthermore, compared with the source of industrial enterprises, road traffic, house cooking and winter heating contribute most of CO [75], while they are not the prime supervising targets in this inspection. In 2016, the CO emitted from automobiles in China is more than 30 million tons, accounting for 80 percent of total emissions [76]. Coincidentally, 20 provinces involving 187 sample cities were inspected in summer or winter, both of which are peak seasons for private transportation, and the latter for winter heating. Thus, the CO emissions may be more difficult to be controlled in a short time.

In a similar vein, O₃, the main component of photochemical smog, is equipped with a more complex formation mechanism in which the primary pollutants, like nitrogen oxide and hydrocarbon, and the secondary pollutants, such as formaldehyde and acrolein, generate a photochemical reaction in ultraviolet light from the sun [77]. Especially the NO_x, as one of the major precursors for O₃, can exert a titration effect for O₃ emission [78]. That is, the decrease of NO₂ concentration due to the EICG leads to the subsequent increase of ozone concentration. Besides, once formed steadily in the air, O₃ can spread rapidly with the wind, which further enhances the difficulties to restrict the O₃ emissions in a short period. Given these reasons, the effect of EICG is largely limited in controlling the emissions of CO and O₃.

In addition, the regression coefficients of the control variables demonstrate that weather conditions can affect the air quality improvement significantly, of which rainy and windy weather is conducive to reducing the air pollution, while snowy weather is likely to increase the pollution intensity. As for the air temperature, the result indicates that excessively high air temperature is not conducive to controlling air pollution.

In summary, given that EICG can reduce the air pollution intensity, mainly reflected by PM_{2.5}, PM₁₀, SO₂ and NO₂, the critical role of EICG needs to be widely recognized and its actual implementation should thus be enhanced by the Chinese central government. Specifically, by virtue of the experience obtained in this inspection, it is absolutely necessary to appropriately shift the inspection target from monitoring local polluting firms to supervising local governments' deviation behaviors [79]. Focusing on this target, the EICG teams should resort to the national authority, break down the traditional structure of "from top to bottom" and formulate an independent inspection scheme that is effective for a long time. Therefore, it is also necessary to further implement the rectification performance evaluation and accountability mechanism for local officials according to the inspection outcomes for the regions charged by them. In addition, considering that the implementation of EICG currently does not exert its effect on reducing CO and O₃ pollution as expected, the EICG teams should give top priority to their pollution sources including industrial enterprises, transportation, winter heating, etc., and accordingly design the treatment schemes in later actions of air pollution governance.

Although the positive effect of EICG on air quality improvement during the inspection period has been initially proven, whether this effect can last for a longer time after the inspection remains unknown, which deserves to be further examined. In this regard, this study introduced the time dummy variables before and after the inspection in the aforementioned regression model of Equation (2). Specifically, the period of one month before the inspection (BEFORE1) was used to compare the effect of EICG during the one-month inspection. The periods of three months and six months after the inspection (AFTER3 and AFTER6) were utilized to examine whether there is an attenuation effect of EICG over a longer time.

Table 4 presents the estimation results concerning the attenuation effect of EICG on air quality improvement. The results show that other coefficients for the variable BEFORE1 are positive except O₃ and partly significant at the 1% level, indicating that the pollution intensity during the one-month period before the inspection is higher than that in other time periods. Specifically, the concentrations of PM_{2.5}, PM₁₀, SO₂, NO₂ and CO increase by 1.198 µg/m³, 0.257 µg/m³, 0.126 µg/m³, 0.272 µg/m³ and 0.062 µg/m³, respectively, leading the comprehensive air quality index to rise significantly by 1.550. The underlying reason may be that some polluting firms accelerated their production before the inspection to avoid the potential losses induced by limiting and even stopping production during the inspection demanded by local governments.

Table 4. Attenuation effect of EICG on air quality improvement.

Variable (1)	PM _{2.5} (2)	PM ₁₀ (3)	SO ₂ (4)	NO ₂ (5)	CO (6)	O ₃ (7)	AQI (8)	OPL (9)
BEFORE1	1.198 ** (0.003)	0.257 (0.678)	0.126 (0.531)	0.272 (0.073)	0.062 *** (0.000)	−1.140 *** (0.000)	1.550 ** (0.001)	0.013 (0.167)
EICG	−2.676 *** (0.000)	−6.698 *** (0.000)	−1.858 *** (0.000)	−1.443 *** (0.000)	0.012* (0.020)	0.157 (0.556)	−2.646 *** (0.000)	−0.059 *** (0.000)
AFTER3	−4.867 *** (0.000)	−6.409 *** (0.000)	−0.345 * (0.034)	−0.391 ** (0.001)	−0.052 *** (0.000)	−1.046 *** (0.000)	−5.636 *** (0.000)	−0.112 *** (0.000)
AFTER6	2.604 *** (0.000)	1.299 ** (0.001)	−1.963 *** (0.000)	0.184 * (0.048)	0.049 *** (0.000)	−0.844 *** (0.000)	2.175 *** (0.000)	0.040 *** (0.000)
Constant	91.994 *** (0.000)	82.060 *** (0.000)	40.352 *** (0.000)	48.501 *** (0.000)	1.371 *** (0.000)	18.548 *** (0.000)	99.575 *** (0.000)	2.460 *** (0.000)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Adj. R *	0.2829	0.3103	0.4343	0.4990	0.3971	0.4401	0.2935	0.2910
F value	400.75 ***	456.84 ***	779.01 ***	1010.41 ***	668.55 ***	797.53 ***	422.03 ***	416.90 ***
OBS	257,395	257,395	257,395	257,395	257,395	257,395	257,395	257,395

Note: ***, ** and * refer to $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.

On the contrary, from the estimated coefficients for EICG, we can see a large decrease of various pollutant concentrations during the inspection, ranging from 1.443 $\mu\text{g}/\text{m}^3$ of NO_2 to 6.698 $\mu\text{g}/\text{m}^3$ of PM_{10} and thus a 2.646 reduction of the air quality index, implying that EICG can reduce the air pollution significantly during the inspection period. The coefficients for AFTER3, with a significantly negative value, still exhibit a pollution-reduction effect, even three months after the inspection. However, over a longer time of six months, a majority of the coefficients for AFTER6 tend to be significantly positive, indicating that the pollution intensity has turned to increase six months after the inspection.

To present the effect of EICG on air quality improvement more clearly, we plotted the air pollution changes from one month before the inspection to six months after the inspection. As shown in Figure 1, the concentrations of the pollutants like $\text{PM}_{2.5}$, PM_{10} , NO_2 and AQI first decrease from one month before the inspection to three months after the inspection, and then increase over time, suggesting that the attenuation effect of EICG on air quality improvement exists in the Chinese institutional background. Hypothesis 2 is thus supported. A further explanation for the attenuation effect may be that a number of deviation behaviors, such as selective rectification, perfunctory rectification and symbolic rectification, are deployed by local governments and polluting firms to cope with the EICG. Those rectification measures are taken during a short time in order to specifically cater to the campaign-based inspection and thus probably fail to be effective once the inspection is over.

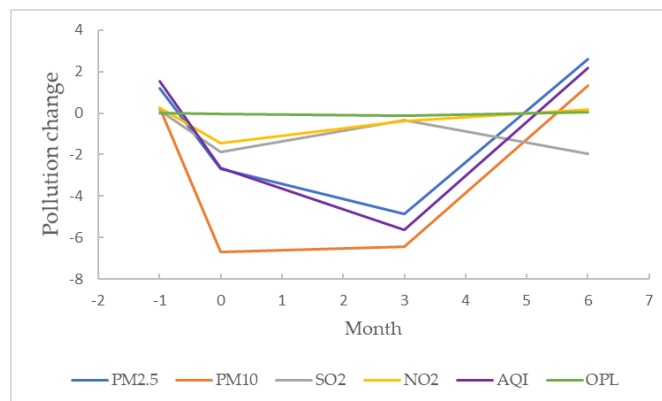


Figure 1. Effect of EICG on air quality improvement.

Considering that the attenuation effect of EICG on air quality improvement has been verified, the central government should attach more importance to this phenomenon and employ necessary measures to hamper the air pollution rebound. One practical approach is to transform the campaign-based regulation into a routine environmental inspection mechanism [80]. According to the inspection procedures strictly set by the central government, the EICG teams should not only focus on discovering the pollution problems and requiring rectification, but also concern themselves more with implementing random inspections over local enforcement of rectification. Especially targeting some rectification tasks like updating and restructuring production facilities that require a longer time, it is even more necessary for the EICG teams to review the rectification effect three to six months after the inspection, in order to avoid local governments' perfunctory rectification or symbolic rectification to a large extent.

5.3. Moderating Effect of Public Engagement

By adding the interaction term of EICG with public engagement into the model, we obtained the results of whether public engagement would moderate the effect of EICG on air quality improvement. As shown in Table 5, for different dependent variables including $\text{PM}_{2.5}$, PM_{10} , NO_2 and AQI, the coefficients of public engagement are all significantly negative at the 0.1% level, indicating that public engagement is conducive to promoting the air quality improvement. In addition, the coefficients of interaction terms for $\text{PM}_{2.5}$, PM_{10} , NO_2 and AQI are negative, at least at the 5% level of significance, implying that public engagement may enhance the air pollution governance effect of EICG. In other

words, public engagement and EICG play joint roles in improving air quality. Hypothesis 3 is thus supported.

Table 5. Moderating effect of public engagement.

Variable (1)	PM _{2.5} (2)	PM ₁₀ (3)	SO ₂ (4)	NO ₂ (5)	CO (6)	O ₃ (7)	AQI (8)	OPL (9)
EICG	−2.210 *** (0.000)	−5.149 *** (0.000)	−1.555 *** (0.000)	−1.007 *** (0.000)	0.000 (0.971)	0.218 (0.460)	−1.918 *** (0.000)	−0.041 *** (0.000)
PUBEN	−1.527 *** (0.000)	−1.950 *** (0.000)	−0.196 (0.076)	−0.516 *** (0.000)	−0.014 *** (0.000)	−0.163 (0.275)	−1.624 *** (0.000)	−0.034 *** (0.000)
EICG *PUBEN	−1.972 * (0.041)	−4.461 ** (0.003)	1.023 * (0.036)	−2.123 *** (0.000)	0.026* (0.046)	1.755 ** (0.007)	−2.299 * (0.042)	−0.059 * (0.011)
Constant	92.210 *** (0.000)	82.428 *** (0.000)	40.405 *** (0.000)	48.508 *** (0.000)	1.371 *** (0.000)	18.670 *** (0.000)	99.835 *** (0.000)	2.456 *** (0.000)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Adj. R *	0.2824	0.3098	0.4332	0.4992	0.3964	0.4398	0.2930	0.2905
F value	401.34 ***	457.723 ***	778.436 ***	1014.976 ***	669.021 ***	799.698 ***	422.594 ***	417.606 ***
OBS	257,395	257,395	257,395	257,395	257,395	257,395	257,395	257,395

Note: ***, ** and * refer to $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.

Figure 2 presents the pollution changes induced by EICG, public engagement, and their interaction terms. The pollution changes with almost all negative values show that the combined effect of EICG and public engagement can reduce the concentrations of the pollutants like PM_{2.5}, PM₁₀ and NO₂, and consequently improve air quality reflected by AQI and OPL. The results as shown in Figure 2 imply that public engagement is a vital factor affecting the air pollution governance effect of EICG. To date, public engagement has gradually become one of the necessary elements in the Chinese environmental governance system, deemed as equally important to other roles like governments and enterprises. Especially during this inspection, the public contributes to the whole inspection process. Through the specific complaint channels including telephone hotlines and mailboxes, the public delivered 135,000 pollution clues to the inspection teams. When the inspection teams made a further investigation about local pollution situations, the public took advantage of their local knowledge to help inspection teams identify the pollution sources rapidly and generate rectification lists. Even when the one-month inspection was over, the public still supervised the rectification effect, especially targeting the problem lists previously disclosed, as well as monitoring whether local governments and polluting firms maintain local pollution governance. In a word, public engagement has become a vital force to monitor local environmental enforcement during this inspection, not only reducing the information asymmetry between central and local governments but also destroying the collusions between local governments and polluting firms to a large extent.

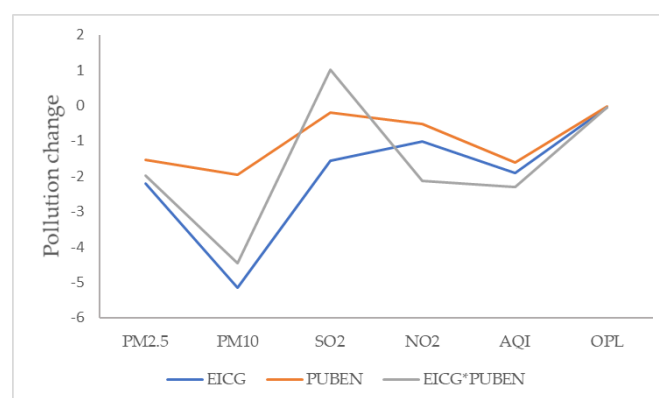


Figure 2. Moderating effect of public engagement.

Given the positive role of public engagement in the relationship between EICG and air quality improvement, governments at all levels should pay more attention to public engagement in the

regulatory effect of EICG on pollution abatement. On the one hand, in order to encourage the public to actively contribute to pollution governance, the governments can increase publicity efforts and invest more in public education about pollution hazards and pro-environmental knowledge [81]. On the other hand, in terms of the public's role during the inspection, the public's rights to information and supervision on local pollution should be further guaranteed. In addition to providing an 7/24 complaint platform in the inspection, EICG teams should also ascertain the channels and scopes for the public to enhance their actual engagement in the whole inspection process, covering pollution clues collection, field investigation, report generation and rectification enforcement. At the same time, some community residents or local environmental Non-Governmental Organization (NGO) members that possess local knowledge about the surrounding environment can be introduced as independent scrutinizers in future inspection [82]. To further facilitate the public's long-term engagement in local pollution governance, the central government could even set up a regular reward mechanism in which a portion of the penalty for environmental violations is offered as a reward to individuals and organizations for their substantial contributions in the inspection.

5.4. Robustness Check

Considering that the Overall Pollution Level (OPL), similarly to the Air Quality Index (AQI), also reflects the overall air quality, the study introduced OPL as an alternative variable into the abovementioned three regression models to check the robustness of the results concerning AQI. As shown in columns (8) and (9) of Tables 3–5, the results of both AQI and OPL as dependent variables are strongly coherent, which basically validate the robustness of these results.

At the same time, to test the robustness of the effects of EICG on air quality reported in columns (2)–(8) of Table 3, we utilized the data from different time windows (encompassing 10, 20 or 30 days before and after the one-month inspection) as an alternative for EICG, which lasted only one month, and repeated regression analysis. The results shown in Table 6 indicated that most of the coefficients for EICG $\pm$ 10, EICG $\pm$ 20 and EICG $\pm$ 30 are significantly negative, which is in accord with the above-mentioned regression results in Table 3.

Table 6. Robustness check.

Variable		PM _{2.5}	PM ₁₀	SO ₂	NO ₂	CO	O ₃	AQI	OPL
Main effect	EICG $\pm$ 10	−0.918 ** −0.003	−3.763 *** 0	−0.937 *** 0	−0.844 *** 0	0.030 *** 0	−0.002 −0.993	−0.574 −0.114	−0.021 ** −0.005
	EICG $\pm$ 20	−1.216 *** 0	−3.937 *** 0	−0.685 *** 0	−0.550 *** 0	0.038 *** 0	0.161 −0.376	−0.847 ** −0.007	−0.033 *** 0
	EICG $\pm$ 30	−1.054 *** 0	−3.891 *** 0	−0.507 *** 0	−0.504 *** 0	0.035 *** 0	0.609 *** 0	−0.742 ** −0.009	−0.030 *** 0
Attenuation effect	BEFORE6	−0.314 −0.127	0.519 −0.103	3.290 *** 0	−0.262 ** −0.001	−0.019 *** 0	3.399 *** 0	0.15 −0.534	0.011 * −0.033
	BEFORE1	1.547 *** 0	−0.012 −0.986	−2.332 *** 0	0.477 ** −0.003	0.078 *** 0	−3.636 *** 0	1.580 ** −0.002	0.008 −0.439
	AFTER1	−2.069 *** 0	−4.984 *** 0	1.205 *** 0	−0.341 * −0.037	0.020 *** 0	3.549 *** 0	−1.191 * −0.018	−0.044 *** 0
	AFTER6	0.464 * −0.024	−0.926 ** −0.004	−1.598 *** 0	−0.011 −0.883	0.016 *** 0	−1.201 *** 0	−0.392 −0.103	−0.005 −0.273
Moderating effect	EICG	−1.967 *** (0.000)	−4.869 *** 0	−1.583 *** 0	−1.005 *** 0	0.003 −0.555	0.653 * −0.025	−1.548 ** −0.002	−0.036** −0.001
	PUBEN'	−0.838 *** 0	−1.172 ** −0.001	−0.106 −0.35	−0.456 *** 0	−0.009 ** −0.003	−0.249 −0.1	−0.932 *** 0	−0.017 ** −0.001
	EICG *	−3.226 **	−6.123 ***	1.193 *	−2.261 ***	0.009	−0.418	−4.277 ***	−0.089 ***
	PUBEN'	−0.001	0	−0.018	0	−0.497	−0.533	0	0

Note: ***, ** and * refer to $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.

In addition, we further adopted the period of one month and six months both before and after the inspection (BEFORE6, BEFORE1, AFTER1 and AFTER6) to conduct a regression analysis again to check the robustness of the attenuation effect of EICG on air quality improvement. The results shown in Table 6 indicate that, in most cases such as PM_{2.5}, PM₁₀, NO₂ and AQI, EICG reduces air pollution

one month after the inspection compared with the results before the inspection. However, this effect is weakened over a longer time of six months compared with the results one month after the inspection. Taking the effect of EICG on $PM_{2.5}$ as an example, the coefficients of BEFORE1, AFTER1 and AFTER6 are all significant, but changing from positive to negative and then positive again, implying that $PM_{2.5}$ pollution decreases one month after the inspection but increases six months later. Thus, the conclusion of the attenuation effect of EICG is also robust.

Finally, considering that the public's environmental engagement behaviors usually lag behind their information searching behaviors, this study utilized the data of search volumes of the public during one month before the inspection as a substitute indicator to test the robustness of the results related to the moderating role of public engagement. As shown in Table 6, the results are consistent with the aforementioned ones in Table 5, with the effects of the interaction terms of EICG and public engagement unchanged, which implies that the results in Table 5 are relatively stable.

5.5. Further Analysis

Given the climate differences between the northern and southern regions in China, the Chinese government has instituted a winter heating policy in northern China, of which the heating period generally lasts from November of one year to March of the following year. Winter heating has been regarded as a main contributor to Chinese serious air pollution [83]. Thus, taking several major air indexes significantly reduced by EICG as examples, this study further examined whether there is a difference for the abovementioned regression results in different samples of the heating period and non-heating period.

As illustrated in Table 7, in the subsample of the heating period, the coefficients for BEFORE1 are all positive and statistically significant, implying that the air pollution in cities of the heating period (CHP) was still serious one month before the inspection. By contrast, although the coefficients for EICG in the subsample decrease relative to those for BEFORE1, almost all of them are still positive except for PM_{10} and AQI, implying that EICG does not play its role well enough in the current month of inspection. However, the coefficients for AFTER3 in the subsample are all with significantly negative signs, indicating that the implementation of EICG reduces air pollution during three months after the inspection. The change of coefficients for EICG and AFTER3 from positive to negative provides evidence that a lagged effect of EICG on air quality improvement in CHP exists. A possible explanation for the lagged effect is that the winter heating policy is taken for granted by local governments and the public, and thus it is unlikely to stop heating or downsize the heating areas in the heating period. The air pollution that results from coal fuel for heating is thus difficult to be reduced in a short time. By contrast, in the subsample of the non-heating period, the coefficients for BEFORE1, EICG and AFTER3 are all with significantly negative signs, demonstrating that EICG improves the air quality in a faster and more effective manner in cities during the non-heating period (CNHP). However, it should be noted that for the samples of both CHP and CNHP, the coefficients for AFTER6 are positive except SO_2 , which verifies the attenuation effect of EICG on air quality improvement over a longer time.

Furthermore, to achieve the target of reducing air pollution in a more efficient manner, the Chinese central government has also identified three regions, including the Beijing–Tianjin–Hebei region, the Yangtze River Delta region and the Fenhe–Weihe plain, and then implemented tougher supervision. Targeting their more severe air pollution, the central government has launched regional collaborative governance in these three regions. Under this circumstance, this study split the samples into two categories: cities specially monitored (CSM) and cities not specially monitored (CNSM), and then examined their difference between the effects of EICG on air quality improvement.

Table 8 presents the regression results for six kinds of air indexes. It is found that in CSM, the air quality is still worse one month before the inspection. Based on the results for EICG, we can see that EICG reduces the PM_{10} and NO_2 pollution of CSM in the current month, while the reduction of $PM_{2.5}$, AQI and OPL appears three months after the inspection and even six months for the reduction of SO_2 . By contrast, in CNSM, the air quality is improved in a rapid manner due to the implementation of

EICG. The possible reason for the differentiated results may be that in the cities specially monitored, stricter pollution problems have been discovered by the EICG teams, which implies that the subsequent rectification requires a longer time to be effective, thus leading to the lagged effect of EICG in controlling air pollution. Furthermore, it is notable that most of the coefficients for AFTER6 in both subsamples are positive, which also verifies the attenuation effect of EICG on air quality improvement.

Considering the difference between the pollution governance effects in different cities classified by heating period and specially monitored regions, the EICG teams should implement a more accurate inspection scheme. On the one hand, the EICG teams can prolong the time of inspection over cities during the heating period, and urge local governments to promulgate measures to encourage the public's pro-environmental behaviors in the heating period, such as increasing the discount for public transportation and rewarding for behaviors of energy conservation. At the same time, given that the severe air pollution in the winter heating period mainly arises from traditional coal-burning boiler heating [84], the EICG teams should compel local governments to take accurate measures including gradually eliminating coal-fired boilers with exceeding emissions, introducing the "convert coal to gas" or the "convert coal to electricity" practice, and implementing off-peak heating, in order to address this issue to the utmost extent. On the other hand, as for the more complex pollution situation in specially monitored regions, the EICG teams should pay more attention to whether those target enterprises have implemented countermeasures in place. For instance, given that the thermal power industry is one of the major emitters for various pollutants like SO_2 and NO_x , the enterprises in this industry should be required to employ desulfurization and denitration technologies or facilities to reduce the emissions of these pollutants [85]. Targeting at reducing the concentration of PM above guideline, especially that originating from enterprises of the steel and cement industries, it is imperative to compulsively require these enterprises to upgrade the dedusting equipment and to utilize clean technologies. Along with these specific measures, the air pollution in the heating period or in specially monitored regions could be effectively controlled.

Table 7. Heterogeneous influences of the heating period.

Variable	PM _{2.5}		PM ₁₀		SO ₂		NO ₂		AQI		OPL	
	CHP	CNHP	CHP	CNHP	CHP	CNHP	CHP	CNHP	CHP	CNHP	CHP	CNHP
BEFORE1	39.165 *** 0	−2.414 *** 0	60.403 *** 0	−4.690 *** 0	8.274 *** 0	−0.856 *** 0	13.080 *** 0	−0.693 *** 0	45.090 *** 0	−2.509 *** 0	0.657 *** 0	−0.044 *** 0
EICG	2.856	−3.294 ***	−8.395**	−6.331 ***	4.924 ***	−3.115 ***	6.762 ***	−1.913 ***	−0.281	−2.931 ***	0.036	−0.060 ***
	−0.21	0	−0.009	0	0	0	0	0	−0.931	0	−0.445	0
AFTER3	−20.375 ***	−3.096 ***	−24.904 ***	−4.993 ***	−5.005 ***	−0.638 ***	−5.248 ***	−0.311 *	−22.010 ***	−3.761 ***	−0.429 ***	−0.073 ***
	0	0	0	0	0	0	0	−0.01	0	0	0	0
AFTER6	7.485 ***	1.386 ***	7.290 ***	0.547	−0.117	−0.229**	1.558 ***	0.184	7.340 ***	0.965 ***	0.149 ***	0.015 *
	0	0	0	−0.149	−0.797	−0.008	0	−0.058	0	0	0	−0.011
Constant	184.974 ***	84.834 ***	223.168 ***	77.214 ***	103.387 ***	25.112 ***	76.626 ***	48.070 ***	210.020 ***	93.260 ***	4.350 ***	2.378 ***
	0	0	0	0	0	0	0	0	0	0	0	0
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Adj. R *	0.269	0.275	0.2844	0.3009	0.4925	0.4223	0.4524	0.5068	0.2708	0.2922	0.2816	0.2786
F value	115.987 ***	330.381 ***	125.208 ***	374.680 ***	304.332 ***	635.564 ***	259.178 ***	893.053 ***	117.060 ***	359.457 ***	123.530 ***	336.363 ***
OBS	36,880	220,515	36,880	220,515	36,880	220,515	36,880	220,515	36,880	220,515	36,880	220,515

Note: ***, **, and * refer to $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively.

Table 8. Heterogeneous influences of specially monitored regions.

Variable	PM _{2.5}		PM ₁₀		SO ₂		NO ₂		AQI		OPL	
	CSM	CNSM	CSM	CNSM	CSM	CNSM	CSM	CNSM	CSM	CNSM	CSM	CNSM
BEFORE1	12.992 ***	−3.636 ***	17.548 ***	−6.725 ***	1.956 ***	−0.588 **	1.901 ***	−0.351 *	15.000 ***	−3.950 ***	0.197 ***	−0.063 ***
	0	0	0	0	0	−0.003	0	−0.028	0	0	0	0
EICG	0.262	−3.670 ***	−3.096 *	−7.844 ***	0.22	−2.646 ***	−2.823 ***	−0.683 ***	1.293	−4.024 ***	0.011	−0.084 ***
	−0.776	0	−0.02	0	−0.662	0	0	0	−0.218	0	−0.593	0
AFTER3	−4.656 ***	−4.727 ***	−4.065 ***	−7.184 ***	2.580 ***	−1.480 ***	−0.854 **	−0.147	−3.358 ***	−6.358 ***	−0.075 ***	−0.123 ***
	0	0	0	0	0	0	−0.002	−0.251	0	0	0	0
AFTER6	1.399 *	3.327 ***	−0.661	2.485 ***	−4.208 ***	−0.973 ***	0.331	0.257**	0.29	3.261 ***	−0.001	0.063 ***
	−0.015	0	−0.426	0	0	0	−0.12	−0.009	−0.659	0	−0.913	0
Constant	115.364 ***	53.527 ***	113.195 ***	40.076 ***	45.424 ***	40.023 ***	53.225 ***	23.759 ***	125.538 ***	58.733 ***	2.932 ***	1.626 ***
	0	0	0	0	0	0	0	0	0	0	0	0
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Adj. R *	0.2543	0.2619	0.2969	0.2724	0.3911	0.4595	0.4087	0.4672	0.2569	0.2684	0.26	0.2601
F value	302.588 ***	351.610 ***	374.372 ***	370.926 ***	569.002 ***	841.248 ***	612.146 ***	867.670 ***	306.682 ***	363.504 ***	311.726 ***	348.397 ***
OBS	71,618	185,777	71,618	185,777	71,618	185,777	71,618	185,777	71,618	185,777	71,618	185,777

Note: ***, ** and * refer to $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.

6. Conclusions and Contributions

6.1. Conclusions

Utilizing the daily data of 249 prefecture-level Chinese cities from 1 June 2015 to 31 May 2018, this study provides a number of insights into the effect of EICG on air quality improvement and the role of public engagement in their relationship. In addition, the heterogeneous effects of EICG in different subsamples classified by heating period and specially monitored regions were also further explored. Several findings can be concluded. First, EICG is conducive to reducing the concentrations of $PM_{2.5}$, PM_{10} , SO_2 and NO_2 , and therefore to improving the overall air quality, reflected by AQI and OPL. Second, the positive influence of EICG on the air quality is weakened six months after the inspection, namely the attenuation effect. Third, public engagement is shown to enhance the positive association between EICG and air quality improvement. Finally, EICG promotes an improvement in air quality up to three months after the inspection in cities during the heating period, while the positive effect has existed from one month before the inspection to three months after the inspection in cities during the non-heating period. In addition, compared with the instant effect in cities not specially monitored, there is a lagged effect of EICG in controlling the air pollution in cities specially monitored. However, it is also worth noting that the attenuation effect of EICG on air quality improvement is observed in all four groups of subsamples.

6.2. Theoretical Contributions

The current study furnishes valuable theoretical contributions. On the one hand, despite that prior research has examined the impacts of various regulatory instruments on air pollution governance, what remains relatively less explored is whether campaign-based regulation, represented by EICG, plays a crucial role in air quality improvement. Focusing on EICG, this study contributes to extant literature as we verified its positive influences on overall air quality and the abatement of air pollutant emissions like $PM_{2.5}$, PM_{10} , SO_2 and NO_2 , as well as the attenuation of these effects. On the other hand, by illuminating the moderating role of public engagement in the association between EICG and air quality improvement, this study further enhances our understanding about how EICG and public engagement, representing a formal regulation and informal one, respectively, interact to control air pollution. Furthermore, given the specific climate conditions and regional pollution management in China, this study considers two heterogeneous factors, including heating period and specially monitored regions, when evaluating the impacts of EICG on air quality improvement, which is conducive to further explicating the variance for the regulatory effect of EICG.

6.3. Limitations and Future Opportunities

Some limitations in the study remain to be considered. In China, to solve the challenges arising from air pollution, the central government has enacted various regulatory instruments, ranging from revising the Air pollution Prevention and Control Law to initiating the campaign-based environmental inspection. Although this study has addressed the impact of EICG on air quality improvement, further studies can be conducted to compare the regulatory efficiencies of these pollution governance instruments. In addition, due to the availability of daily data, this study measures public engagement from the perspective of Internet searching channels, rather than other possible channels like complaint letters or environmental proposals. Future research can further investigate whether there is a difference regarding the role of public engagement measured by the data from various channels.

Author Contributions: Conceptualization, F.X. and M.T.; methodology, M.T.; writing—original draft preparation, F.X. and J.Y.; writing—review and editing, G.X. All authors have read and agree to the published version of the manuscript.

Funding: This research was funded by the Humanities and Social Science Fund of the Ministry of Education of China [Grant No. 16YJA630061].

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zheng, S.M.; Yi, H.T.; Li, H. The impacts of provincial energy and environmental policies on air pollution control in China. *Renew. Sust. Energy Rev.* **2015**, *49*, 3863–3894. [\[CrossRef\]](#)
2. MEE. Ministry of Ecology and Environment of the People's Republic of China. 2019. Available online: http://www.mee.gov.cn/xxgk/xxgk15/201901/t20190107_688741.html (accessed on 7 January 2019).
3. CELP. Center for Environmental Law & Policy, Yale University, Center for International Earth Science Information Network, Columbia University, World Economic Forum. 2018 Environmental Performance Index. Available online: <https://epi.envirocenter.yale.edu/> (accessed on 1 January 2018).
4. Lelieveld, J.; Evans, J.S.; Fnais, M.; Giannadaki, D.; Pozzer, A. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* **2015**, *525*, 367–371. [\[CrossRef\]](#) [\[PubMed\]](#)
5. WHO. World Health Organization. 2018. Available online: https://www.who.int/gho/publications/world_health_statistics/en/ (accessed on 1 January 2018).
6. WHO. Organization for Economic Co-Operation and Development, International Transport Forum. 2014. Available online: <http://www.oecd.org/itf/> (accessed on 21 May 2014).
7. Zhang, B.; Chen, X.L.; Guo, H.X. Does central supervision enhance local environmental enforcement? Quasi-experimental evidence from China. *J. Public Econ.* **2018**, *164*, 70–90. [\[CrossRef\]](#)
8. Pang, R.; Zheng, D.; Shi, M.J.; Zhang, X.L. Pollute first, control later? Exploring the economic threshold of effective environmental regulation in China's context. *J. Environ. Manag.* **2019**, *248*. [\[CrossRef\]](#)
9. Qi, Y.; Zhang, L.Y. Local environmental enforcement constrained by central-local relations in China. *Environ. Policy Gov.* **2014**, *24*, 204–215. [\[CrossRef\]](#)
10. Yu, X.Y. Central-local conflicts in China's environmental policy implementation: The case of the sloping land conversion program. *Nat. Hazards* **2016**, *84*, S77–S96. [\[CrossRef\]](#)
11. Cole, M.A.; Elliott, R.J.R.; Shimamoto, K. Industrial characteristics, environmental regulations and air pollution: An analysis of the UK manufacturing sector. *J. Environ. Econ. Manag.* **2005**, *50*, 121–143. [\[CrossRef\]](#)
12. Wang, H.; Liu, H.F. Foreign direct investment, environmental regulation, and environmental pollution: An empirical study based on threshold effects for different Chinese regions. *Environ. Sci. Pollut. Res.* **2019**, *26*, 5394–5409. [\[CrossRef\]](#)
13. Greenstone, M.; Hanna, R. Environmental regulations, air and water pollution, and infant mortality in India. *Am. Econ. Rev.* **2014**, *104*, 3038–3072. [\[CrossRef\]](#)
14. Zhou, Q.; Zhang, X.L.; Shao, Q.L.; Wang, X.L. The non-linear effect of environmental regulation on haze pollution: Empirical evidence for 277 Chinese cities during 2002–2010. *J. Environ. Manag.* **2019**, *248*. [\[CrossRef\]](#)
15. Halkos, G.E.; Tzeremes, N.G. Measuring the effect of Kyoto Protocol agreement on countries' environmental efficiency in CO2 emissions: An application of conditional full frontiers. *J. Prod. Anal.* **2014**, *41*, 367–382. [\[CrossRef\]](#)
16. Elnaboulsi, J.C.; Daher, W.; Saglam, Y. On the social value of publicly disclosed information and environmental regulation. *Resour. Energy Econ.* **2018**, *54*, 1–2. [\[CrossRef\]](#)
17. Habib, A.; Bhuiyan, M.B.U. Determinants of monetary penalties for environmental violations. *Bus. Strateg. Environ.* **2017**, *26*, 754–775. [\[CrossRef\]](#)
18. Elmore, R.F. Backward mapping: Implementation research and policy decisions. *Polit. Sci. Q.* **1979**, *94*, 601–616. [\[CrossRef\]](#)
19. Parkins, J.R.; Rollins, C.; Anders, S.; Comeau, L. Predicting intention to adopt solar technology in Canada: The role of knowledge, public engagement, and visibility. *Energy Policy* **2018**, *114*, 114–122. [\[CrossRef\]](#)
20. Wang, L.L.; Watanabe, T. Effects of environmental policy on public risk perceptions of haze in Tianjin city: A difference-in-differences analysis. *Renew. Sust. Energy Rev.* **2019**, *109*, 199–212. [\[CrossRef\]](#)
21. Tu, Z.G.; Hu, T.Y.; Shen, R.J. Evaluating public participation impact on environmental protection and ecological efficiency in China: Evidence from PITI disclosure. *China Econ. Rev.* **2019**, *55*, 1–123. [\[CrossRef\]](#)
22. Tang, P.C.; Zeng, H.; Fu, S.K. Local government responses to catalyse sustainable development: Learning from low-carbon pilot programme in China. *Sci. Total Environ.* **2019**, *689*, 1054–1065. [\[CrossRef\]](#)

23. Whitmarsh, L.; Corner, A. Tools for a new climate conversation: A mixed-methods study of language for public engagement across the political spectrum. *Glob. Environ. Change-Human Policy Dimens.* **2017**, *42*, 122–135. [\[CrossRef\]](#)
24. Agostino, D.; Arnaboldi, M. A measurement framework for assessing the contribution of social media to public engagement: An empirical analysis on Facebook. *Public Manag. Rev.* **2016**, *18*, 1289–1307. [\[CrossRef\]](#)
25. Huang, G.L. PM2.5 opened a door to public participation addressing environmental challenges in China. *Environ. Pollut.* **2015**, *197*, 313–315. [\[CrossRef\]](#)
26. Fedorenko, I.; Sun, Y.X. Microblogging-based civic participation on environment in China: A case study of the PM 2.5 campaign. *Voluntas* **2016**, *27*, 207–2105. [\[CrossRef\]](#)
27. Li, L.; Xia, X.H.; Chen, B.; Sun, L.X. Public participation in achieving sustainable development goals in China: Evidence from the practice of air pollution control. *J. Clean Prod.* **2018**, *201*, 499–506. [\[CrossRef\]](#)
28. MEE. Ministry of Ecology and Environment of the People's Republic of China. 2018. Available online: http://www.mee.gov.cn/gkml/sthjbgw/qt/201801/t20180118_429903.htm (accessed on 18 January 2018).
29. Dong, B.M.; Gong, J.; Zhao, X. FDI and environmental regulation: Pollution haven or a race to the top? *J. Regul. Econ.* **2012**, *41*, 216–237. [\[CrossRef\]](#)
30. Li, X.L.; Yang, X.J.; Wei, Q.; Zhang, B. Authoritarian environmentalism and environmental policy implementation in China. *Resour. Conserv. Recycl.* **2019**, *145*, 86–93. [\[CrossRef\]](#)
31. Konisky, D.M. Regulatory competition and environmental enforcement: Is there a race to the bottom? *Am. J. Polit. Sci.* **2007**, *51*, 853–872. [\[CrossRef\]](#)
32. Naiker, Y.; Diab, R.D.; Zunckel, M.; Hayes, E.T. Introduction of local air quality management in South Africa: Overview and challenges. *Environ. Sci. Policy.* **2012**, *17*, 62–71. [\[CrossRef\]](#)
33. CPGC. The Central People's Government of China. 2017. Available online: http://www.gov.cn/xinwen/2017-12/28/content_5251261.htm (accessed on 28 December 2017).
34. Sueyoshi, T.; Yuan, Y. China's regional sustainability and diversified resource allocation: DEA environmental assessment on economic development and air pollution. *Energy Econ.* **2015**, *49*, 239–256. [\[CrossRef\]](#)
35. Zhang, Y.; Wang, J.R.; Xue, Y.J.; Yang, J. Impact of environmental regulations on green technological innovative behavior: An empirical study in China. *J. Clean Prod.* **2018**, *188*, 763–773. [\[CrossRef\]](#)
36. Wang, Z.H.; Zhang, B.; Zeng, H.L. The effect of environmental regulation on external trade: Empirical evidences from Chinese economy. *J. Clean Prod.* **2016**, *114*, 55–61. [\[CrossRef\]](#)
37. Xie, R.H.; Yuan, Y.J.; Huang, J.J. Different types of environmental regulations and heterogeneous influence on “Green” productivity: Evidence from China. *Ecol. Econ.* **2017**, *132*, 104–112. [\[CrossRef\]](#)
38. Zhang, K.K.; Xu, D.Y.; Li, S.R. The impact of environmental regulation on environmental pollution in China: An empirical study based on the synergistic effect of industrial agglomeration. *Environ. Sci. Pollut. Res.* **2019**, *26*, 25775–25788. [\[CrossRef\]](#)
39. Bagayev, I.; Lochard, J. EU air pollution regulation: A breath of fresh air for eastern European polluting industries? *J. Environ. Econ. Manag.* **2017**, *83*, 145–163. [\[CrossRef\]](#)
40. Ouyang, X.; Shao, Q.L.; Zhu, X.; He, Q.Y.; Xiang, C.; Wei, G.E. Environmental regulation, economic growth and air pollution: Panel threshold analysis for OECD countries. *Sci. Total Environ.* **2019**, *657*, 234–241. [\[CrossRef\]](#)
41. Bigger, P. Hybridity, possibility: Degrees of marketization in tradeable permit systems. *Environ. Plan. A* **2018**, *50*, 512–530. [\[CrossRef\]](#)
42. Jiang, L.; Lin, C.; Lin, P. The determinants of pollution levels: Firm-level evidence from Chinese manufacturing. *J. Comp. Econ.* **2014**, *42*, 118–142. [\[CrossRef\]](#)
43. Zhu, J.M.; Chertow, M.R. Authoritarian but responsive: Local regulation of industrial energy efficiency in Jiangsu, China. *Regul. Gov.* **2019**, *13*, 384–404. [\[CrossRef\]](#)
44. Lo, C.W.H.; Fryxell, G.E.; Van Rooij, B.; Wang, W.; Li, P.H. Explaining the enforcement gap in China: Local government support and internal agency obstacles as predictors of enforcement actions in Guangzhou. *J. Environ. Manag.* **2012**, *111*, 227–235. [\[CrossRef\]](#)
45. Li, R.Q.; Zhou, Y.C.; Bi, J.; Liu, M.M.; Li, S.S. Does the central environmental inspection actually work? *J. Environ. Manag.* **2020**, *253*. [\[CrossRef\]](#)
46. Wang, R.X.; Wijen, F.; Heugens, P.P.M.A.R. Government's green grip: Multifaceted state influence on corporate environmental actions in China. *Strateg. Manag. J.* **2018**, *39*, 403–428. [\[CrossRef\]](#)

47. Tian, M.; Xu, G.H.; Zhang, L.Z. Does environmental inspection led by central government undermine Chinese heavy-polluting firms' stock value? The buffer role of political connection. *J. Clean Prod.* **2019**, *236*. [\[CrossRef\]](#)
48. Sosa, B.S.; Porta, A.; Lerner, J.E.C.; Noriega, R.B.; Massolo, L. Human health risk due to variations in PM10-PM2.5 and associated PAHs levels. *Atmos. Environ.* **2017**, *160*, 27–35. [\[CrossRef\]](#)
49. Jia, K.; Chen, S.W. Could campaign-style enforcement improve environmental performance? Evidence from China's central environmental protection inspection. *J. Environ. Manag.* **2019**, *245*, 282–290. [\[CrossRef\]](#) [\[PubMed\]](#)
50. Van Rooij, B. Implementation of Chinese environmental law: Regular enforcement and political campaigns. *Dev. Chang.* **2006**, *37*, 57–74. [\[CrossRef\]](#)
51. Wang, J.; Li, Y.R.; Wang, Q.Y.; Cheong, K.C. Urban-rural construction land replacement for more sustainable land use and regional development in China: Policies and practices. *Land* **2019**, *8*, 171. [\[CrossRef\]](#)
52. Li, X.; Qiao, Y.B.; Zhuc, J.M.; Shi, L.; Wang, Y.T. The "APEC blue" endeavor: Causal effects of air pollution regulation on air quality in China. *J. Clean Prod.* **2017**, *168*, 1381–1388. [\[CrossRef\]](#)
53. Wibeck, V. Enhancing learning, communication and public engagement about climate change - some lessons from recent literature. *Environ. Educ. Res.* **2014**, *20*, 387–411. [\[CrossRef\]](#)
54. Reames, T.G.; Bravo, M.A. People, place and pollution: Investigating relationships between air quality perceptions, health concerns, exposure, and individual - and area-level characteristics. *Environ. Int.* **2019**, *122*, 24–255. [\[CrossRef\]](#)
55. Rydin, Y.; Lee, M.; Lock, S.J. Public engagement in decision-making on major wind energy projects. *J. Environ. Law* **2015**, *27*, 139–150. [\[CrossRef\]](#)
56. Li, X.Y.; Tilt, B. Public engagements with smog in urban China: Knowledge, trust, and action. *Environ. Sci. Policy* **2019**, *92*, 220–227. [\[CrossRef\]](#)
57. Lo, C.W.-H.; Fryxell, G.E.; Wong, W.W.-H. Effective regulations with little effect? The antecedents of the perceptions of environmental officials on enforcement effectiveness in China. *Environ. Manag.* **2006**, *38*, 388–410. [\[CrossRef\]](#) [\[PubMed\]](#)
58. Clements, J.M.; McCright, A.M.; Xiao, C.Y. Green Christians? An empirical examination of environmental concern within the U.S. general public. *Organ. Environ.* **2014**, *27*, 85–102. [\[CrossRef\]](#)
59. Neuman, W.R.; Guggenheim, L.; Jang, S.M.; Bae, S.Y. The dynamics of public attention: Agenda-setting theory meets big data. *J. Commun.* **2014**, *64*, 193–214. [\[CrossRef\]](#)
60. Zhao, X.L.; Zhao, Y.; Zeng, S.X.; Zhang, S.F. Corporate behavior and competitiveness: Impact of environmental regulation on Chinese firms. *J. Clean Prod.* **2015**, *86*, 31–322. [\[CrossRef\]](#)
61. Feres, J.; Reynaud, A. Assessing the impact of formal and informal regulations on environmental and economic performance of Brazilian manufacturing firms. *Environ. Resour. Econ.* **2012**, *52*, 65–85. [\[CrossRef\]](#)
62. Zhang, S.L.; Li, Y.; Hao, Y.; Zhang, Y.P. Does public opinion affect air quality? Evidence based on the monthly data of 109 prefecture-level cities in China. *Energy Policy* **2018**, *116*, 29–311. [\[CrossRef\]](#)
63. Liu, X.H.; Ji, X.; Zhang, D.Q.; Yang, J.J.; Wang, Y.H. How public environmental concern affects the sustainable development of Chinese cities: An empirical study using extended DEA models. *J. Environ. Manag.* **2019**, *251*. [\[CrossRef\]](#)
64. Tang, X.; Chen, W.W.; Wu, T. Do authoritarian governments respond to public opinion on the environment? Evidence from China. *Int. J. Environ. Res. Public Health* **2018**, *15*, 266. [\[CrossRef\]](#)
65. Chen, Y.X.; Zhang, J.; Tadikamalla, P.R.; Gao, X.T. The relationship among government, enterprise, and public in environmental governance from the perspective of multi-player evolutionary game. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3351. [\[CrossRef\]](#)
66. Paco, A.; Lavrador, T. Environmental knowledge and attitudes and behaviours towards energy consumption. *J. Environ. Manag.* **2017**, *197*, 384–392. [\[CrossRef\]](#)
67. Alonso, J.M.; Clifton, J.; Diaz-Fuentes, D. Did new public management matter? An empirical analysis of the outsourcing and decentralization effects on public sector size. *Public Manag. Rev.* **2015**, *17*, 643–660. [\[CrossRef\]](#)
68. Zhang, X.J.; Liu, J.; Zhao, K. Antecedents of citizens' environmental complaint intention in China: An empirical study based on norm activation model. *Resour. Conserv. Recycl.* **2018**, *134*, 121–128. [\[CrossRef\]](#)
69. Oltra, C.; Sala, R.; Boso, A.; Asensio, S.L. Public engagement on urban air pollution: An exploratory study of two interventions. *Environ. Monit. Assess.* **2017**, *189*. [\[CrossRef\]](#) [\[PubMed\]](#)

70. Krupnick, A.J.; Harrington, W.; Ostro, B. Ambient ozone and acute health effects: Evidence from daily data. *J. Environ. Econ. Manag.* **1990**, *18*, 1–18. [\[CrossRef\]](#)
71. Cheng, J.; Liu, Y.Y. The effects of public attention on the environmental performance of high-polluting firms: Based on big data from web search in China. *J. Clean Prod.* **2018**, *186*, 335–341. [\[CrossRef\]](#)
72. Lusi, P.; Khalilpour, K.R.; Andrew, L.; Liebman, A. Short-term residential load forecasting: Impact of calendar effects and forecast granularity. *Appl. Energy* **2017**, *205*, 654–669. [\[CrossRef\]](#)
73. Singh, N.; Murari, V.; Kumar, M.; Barman, S.C.; Banerjee, T. Fine particulates over South Asia: Review and meta-analysis of PM_{2.5} source apportionment through receptor model. *Environ. Pollut.* **2017**, *223*, 121–136. [\[CrossRef\]](#)
74. Wu, Y.Y.; Zhao, P.; Zhang, H.W.; Wang, Y.; Mao, G.Z. Assessment for fuel consumption and exhaust emissions of China's vehicles: Future trends and policy implications. *Sci. World J.* **2012**. [\[CrossRef\]](#)
75. Mukherjee, P.; Viswanathan, S. Contributions to CO concentrations from biomass burning and traffic during haze episodes in Singapore. *Atmos. Environ.* **2001**, *35*, 715–725. [\[CrossRef\]](#)
76. MEE. Ministry of Ecology and Environment of the People's Republic of China. 2017. Available online: http://www.mee.gov.cn/gkml/sthjbgw/qt/201706/t20170603_415265.htm (accessed on 3 June 2017).
77. Mulwijk, C.; Schrijvers, P.J.C.; Wuerz, S.; Kenjeres, S. Simulations of photochemical smog formation in complex urban areas. *Atmos. Environ.* **2016**, *147*, 470–484. [\[CrossRef\]](#)
78. Weissert, L.F.; Salmond, J.A.; Miskell, G.; Alavi-Shoshtari, M.; Grange, S.K.; Henshaw, G.S.; Williams, D.E. Use of a dense monitoring network of low-cost instruments to observe local changes in the diurnal ozone cycles as marine air passes over a geographically isolated urban centre. *Sci. Total Environ.* **2017**, *575*, 67–78. [\[CrossRef\]](#) [\[PubMed\]](#)
79. Zhang, T.Z.; Yao, H. The improvement on the implementation level of environmental policies is demanded in China. *Environ. Sci. Pollut. Res.* **2018**, *25*, 36035–36038. [\[CrossRef\]](#) [\[PubMed\]](#)
80. Johnson, T.R. Regulatory dynamism of environmental mobilization in urban China. *Regul. Gov.* **2016**, *10*, 14–28. [\[CrossRef\]](#)
81. Wang, Y.T.; Sun, M.X.; Yang, X.C.; Yuan, X.L. Public awareness and willingness to pay for tackling smog pollution in China: A case study. *J. Clean Prod.* **2016**, *112*, 1627–1634. [\[CrossRef\]](#)
82. Shen, Y.D.; Ahlers, A.L. Local environmental governance innovation in China: Staging 'triangular dialogues' for industrial air pollution control. *J. Chin. Gov.* **2018**, *3*, 351–369. [\[CrossRef\]](#)
83. Yin, X.M.; Sun, Z.B.; Miao, S.G.; Yan, Q.; Wang, Z.S.; Shi, G.Y.; Li, Z.M.; Xu, W. Analysis of abrupt changes in the PM_{2.5} concentration in Beijing during the conversion period from the summer to winter half-year in 2006–2015. *Atmos. Environ.* **2019**, *200*, 319–328. [\[CrossRef\]](#)
84. Cichowicz, R.; Wielgosinski, G.; Fetter, W. Dispersion of atmospheric air pollution in summer and winter season. *Environ. Monit. Assess.* **2017**, *189*. [\[CrossRef\]](#)
85. Wang, K.; Wei, Y.M.; Huang, Z.M. Environmental efficiency and abatement efficiency measurements of China's thermal power industry: A data envelopment analysis based materials balance approach. *Eur. J. Oper. Res.* **2018**, *269*, 35–50. [\[CrossRef\]](#)

