Article

Policy Implications of the Clean Heating Transition: A Case Study of Shanxi

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Abstract: This study provides empirical evidence of the impact of recentralized governance on environmental performance by examining the implementation of a clean heating transition. It investigated the impact of a centralized clean heating transition on sulfur dioxide (SO_2) levels in Shanxi province from January 2015 to March 2021. Using a difference-in-differences approach, this study found that the centralized clean heating transition led to a significant improvement in air quality; however, the excessive response of Shanxi province prevented adequate heating supply for residents. As a result, the Chinese government had to reverse its initial plans for a coal ban and the promotion of gas plants. This outcome implies that recentralization cannot control the autonomy of local governments in responding to and achieving the central targets, even though it may provide incentives to prioritize environmental issues. The recentralization proved to be ineffective, in contrast to what was theoretically anticipated, and even undermined the energy transition efforts.

Keywords: APACCP; clean heating transition; SO_2; Shanxi province; difference-in-differences; cadre responsibility and evaluation system; target-based implementation; recentralization

1. Introduction

Coal is the primary energy source for winter heating in China; however, it is the main contributor to winter haze [1,2]. The heating system in China was established during the planned economy in the 1950s. Because it was considered public welfare, the central government provided free or highly subsidized coal for heating [3]. Due to limited financial and energy resources, the coal-fired centralized heating system was constructed only in 14 provinces and partially in Henan province, which were north of the border of the Hui River and Qin Mountains [4]. Therefore, cities and provinces such as Shanghai, Jiangsu, and Anhui, which are south of this border, were excluded from the heating zone, even though their average winter temperatures are between 0–10 °C.

Unfortunately, this leads to Chinese citizens experiencing difficult winters. Heating system can be categorized into centralized and decentralized. Centralized heating is supplied by the district and is obtained from coal-fired boilers and combined heat and power plants. Decentralized heating includes heating using individual boilers and coal furnaces, known as the Chinese Kang (stove). The output from most of the district-supplied heating systems are dispatched to urban areas, whereas the majority of rural houses use individual heating. As per official records, approximately seven to eight percent of the total coal consumption in China has been recorded in winter for heating; however, the scattered coal consumption for individual heating has not been fully calculated using official statistics [5,6]. In 2016, the Chinese government publicized the amount of coal consumption for heating as 400 million tons of coal equivalent (Mtce), with the scattered coal consumption accounting for half that amount [4].

Both centralized and decentralized systems have been criticized for predominantly using coal and as being the main contributors of winter air pollution. Firstly, the majority of centralized heating bills continue to be calculated based on the heated area instead of consumption. Hence, even though centralized heating is only available during certain winter periods, the residents are less incentivized to control their usage because they are charged a fixed amount that is independent of the consumption. Secondly, a centralized heating system does not allow individual users to control the temperature; users open windows to adjust room temperature if their rooms are too hot [7]. In contrast, people who reside in houses that lack a temperature control device must endure uncomfortable low temperatures during winters. According to a study, such poor control of room temperature wastes 20–30% of the energy used [8]. Thirdly, Chinese Kangs (stoves), the primary heating equipment for rural residents, are not equipped with air pollution abatement devices and consequently, emit more air pollutants. Fourthly, poor-quality scattered coal is the main fuel used for decentralized heating in rural areas. In addition to having a low combustion efficiency, it also contains higher amounts of ash, sulfur and volatile matter [6]. Therefore, the SO_2 emission factors of scattered coal used in residential stoves and industrial boilers are approximately 11 and 8 times higher, respectively, compared to those of the coal used in centralized power generators [9].

Since early 2013, the capital city of Beijing has suffered from haze episodes with high concentrations of particulate matter, especially in winter. Given the significant adverse influence of winter haze on public health and social stability, the Chinese government has increasingly emphasized air pollution control. The State Council published the Action Plan for Air Pollution Prevention and Control (2013–2017) (hereafter APAPPC 2013–2017) and outlined ten measures (such as enhancing overall treatment and reducing discharges of multiple pollutants, adjusting and optimizing industrial and energy structures, and increasing the supply of clean energy) to improve the nation-wide air quality. The Chinese premier, Li Keqiang, declared 'war on smog' in his first government work report at the 2014 National People's Congress and prioritized the air pollution agenda; however, air pollution episodes have frequently been witnessed [10,11]. The Beijing municipal government was forced to issue the first-ever 'red alert' in December 2015 and again in December 2016. According to the Heavy Air Pollution Contingency Plan of Beijing, the red alert should be announced when authorities forecast more than three consecutive days of severe air pollution associated with air quality index (AQI) above 300 [12]. Following the red alert-related emission reduction measures, schools and kindergartens were suspended, enterprises and institutions were asked to implement flexible work systems, only half the vehicles were allowed to run under the odd-even license plate policy, all outdoor construction work was put off, and listed factories that contributed to pollution were shut down temporarily [12,13].

The central government publicized the urgency and seriousness of the issue, as the air pollution in Beijing was severe until a year before the deadline of the APACCP 2013–2017. At the 14th meeting of the Central Financial and Economic Leading Group in December 2016, Chinese President Xi Jinping stressed on using clean energy for winter heating in northern China to ensure a warm winter for the people and reduce heavy pollution days [14]. The Leading Group is the core of the Communist Party of China (CPC) that governs the economy and discusses related issues. This unprecedented and unexpected statement addressing environmental issues clearly implied that the elite leadership recognized heavy air pollution as detrimental to economic growth and as an urgent problem to solve. Consequently, a series of enhanced policies and measures were issued in 2017 to fulfill the targets set for the APACCP 2013–2017, primarily promoting the coal-to-gas, coal-to-electricity transition. Both President Xi and Premier Li reiterated the importance of environmental protection and clean heating transition in 2017. Moreover, as the initial transition targets continuously increased and environmental inspections were strengthened by the central leadership, the transition was highly centralized.

Because the Chinese government has assigned performance targets to environmental and energy concerns under the cadre responsibility and evaluation system to enhance policy implementation, questions on the effectiveness of target-based implementation have been centered on studies of the environmental governance in China. Theoretically, the cadre responsibility and evaluation system would incentivize local cadres and officials to prioritize environmental policies because environmental performance had been added to the cadre evaluation criteria. However, existing literature suggests that the target-based approach creates an implementation gap due to poor incentives and structural shortcomings. Because the Chinese central government places greater importance on economic growth than environmental protection, local governments do not have sufficient incentives to implement its environmental policies and prioritize economic tasks that materialize their performance in the short term [15]. The cadre has a high turnover rate due to the central government repressing local protectionism. Hence the officers have limited time to impress higher-level governments and advance their careers [16]. Central state-owned enterprises (SOEs), which have long defied environmental regulations under the protection of the central government in order to generate better economic outcomes, have tacitly supported local protectionism. Environmental protection policies have loosely enforced local enterprises in pursuit of better economic outcomes for promotion [17]. In summary, local cadres and officials have put more effort into what their superiors prioritize [18].

Another group of existing literature points out the structural shortcomings that arise due to the local governments being held responsible for the tasks of implementation, monitoring, and verification of environmental policies. Therefore, the cadre responsibility and evaluation system itself have caused many endogenous problems, such as lack of reliable energy data, data falsification, and collusion to fake the environmental performance [19–21]. Two scholars explicitly analyzed these structural shortcomings and described it as "command without control"; the central government sets the policies and performance targets but does not control its implementation and monitoring [22]. Owing to "blaming politics," the central government shifts the responsibilities of implementation and monitoring onto local governments to avoid blame should the environmental policies fail [23]. These studies highlight that the central government must have a clearer intention of environmental protection and an enhanced inspection system to narrow the gap and successfully achieve the intended goals.

As was mentioned earlier, the importance of the clean heating transition on environmental protection and centralized environmental inspection has been supported by the highest authority. However, the impact of the recentralized Chinese environmental governance on air quality and its environmental outcomes have not been sufficiently analyzed; only a few studies have empirically and theoretically studied its impacts on environmental performance [24]. This study seeks to analyze the empirical evidence on the impact of recentralized governance on environmental performance by examining the implementation of the clean heating transition. It was observed that the centralized clean heating transition tasks led to a significant improvement in air quality since the policy intervention, but adequate heating was prevented due to the rapid and large-scale transition. This implies that recentralization may have been able to provide proper incentives to repress local protectionism, but it could not control the autonomy of local governments in responding to and achieving the central targets. As a result, recentralization was not as effective as theoretically anticipated.

The remainder of this paper is structured as follows: Section 2 provides policy background to support the study design. Section 3 briefly reviews the role of cadre responsibility and the evaluation system in Chinese environmental governance and its impact on the policy outcomes. Section 4 explains why this study chose Shanxi province and illustrates the study design and methodology. Section 5 presents the empirical results of the research questions. Section 6 discusses the policy output induced desirable and undesirable

outcomes, namely clean but cold winters. A summary of the key findings and policy implications has been provided in Section 7.

2. Policy Background

In September 2013, the APACCP 2013–2017 was issued with ten measures to improve the nation-wide overall air quality. The goal of the APACCP 2013–2017 was to reduce the PM10 concentrations to 10% of the 2012-levels by 2017 in all the cities with prefecture- and above-levels. The three main regions of Beijing-Tianjin-Hebei, Yangtze delta, and Pearl River delta received the higher PM2.5 reduction targets of 25%, 20%, and 15%, respectively [25]. The peak PM2.5 concentrations might have been reduced by the targets; however, high PM2.5 concentrations were observed during the heating seasons. In fact, the coal switch in the residential sector was mentioned but not strongly encouraged in the APACCP 2013–2017. Accordingly, the Measures to Evaluate the Implementation of the APACCP 2013–2017 only set the evaluation score for the clean management of scattered coal in Beijing, Tianjin, and Hebei provinces. The rest of the northern heating zone was exempted from being assessed for any clean heating-relevant missions [26]. Frequent haze became a source of public unrest as ordinary lives were affected by actions such as closing schools and factories, shutting down highways and airports, and the Chinese government had to take strong action against winter haze.

A series of measures and plans were introduced during the ending year of the APACCP 2013–2017 to encourage meeting the performance targets. Promotion of the clean heating transition was placed in the center of the policy documents. Firstly, the Work Plan for Air Pollution Prevention and Control for the Beijing-Tianjin-Hebei Region and Surrounding Areas in 2017 (hereafter WPACCP 2017), was issued in February 2017. The Ministry of Environmental Protection (MEP) (superseded by the Ministry of Ecology and Environment (MEE) in March 2018) , based on extensive fieldwork and model simulation, selected Beijing, Tianjin, and its surrounding 26 cities, and formed a regional air pollution transmission channel that significantly influenced the PM2.5 concentrations of Beijing. The 26 neighboring cities surrounding Beijing and Tianjin are Shijiazhuang, Tangshan, Langfang, Baoding, Cangzhou, Hengshui, Xingtai, and Handan in Hebei province; Taiyuan, Yangquan, Changzhi, and Jincheng in Shanxi province, Jinan, Zibo, Jining, Dezhou, Liaocheng, Binzhou, and Heze in Shandong province; and Zhengzhou, Kaifeng, Anyang, Hebi, Xinxiang, Jiaozuo, and Puyang in Henan province. Since the formation of the channel, unified emission reduction measures were planned to be carried out in these cities simultaneously to reduce extremely high PM2.5 concentrations in Beijing during heavy pollution episodes. Each city was tasked with completely replacing the coal heating system by 0.05 million to 0.1 million households until October 2017 [27]. The total number ranged from a minimum of 1.4 million to a maximum of 2.8 million households.

The urgency and significance of the clean heating transition were heightened in the second half of 2017, as more rigid measures were introduced. In August 2017, higher targets for the clean heating transition were set for the 2 + 26 key cities throughout the Action Plan for Comprehensive Management of Air Pollution in the Beijing-Tianjin-Hebei and Surrounding Areas in the Autumn and Winter of 2017–2018 (hereafter APCMAP 2017–2018). The Action Plan upgraded the targets with detailed measures aimed at completely replacing coal with gas or electricity in more than 3.55 million households by October 2017 [28]. In December 2017, the National Development and Reform Commission (NDRC) and nine other ministries and commissions jointly issued the Winter Clean Heating Plan for Northern China 2017–2021 (hereafter CWHP 2017–2021). As can be inferred from the name of the plan, it covers all of northern China. It set targets to complete the transition for more than 26 million households and save 150 million Mtce of scattered coal by 2021 in the residential sector. The CWHP 2017–2021 specifically emphasized that the 2 + 26 key cities should lead the transition and allocate higher targets of transition rate compared to other northern heating areas. The clean heating rate in northern China must reach 50% by 2019 and 70% by 2021, at least 90% in the urban areas of the 2 + 26 key cities, above 70% in the prefecture

and urban-rural fringe areas, and more than 40% in the rural by 2019. The targets were 100%, 80%, and 60% respectively for the aforementioned areas by 2021 [4].

The State Council issued the Three-Year Action Plan for Winning the Blue Sky Defense War 2018–2020 (hereafter TYAP 2018–2020) as the APACCP 2013–2017 follow-up policy in June 2018. The three key battle fields were adjusted to the Beijing-Tianjin-Hebei and surrounding areas (Shandong, Shanxi, and Henan provinces), the Yangtze delta, and the Fen-Wei Plain, which stretches over the Shanxi, Shaanxi, and Henan provinces [29]. As the Fen-Wei Plain region is located in the northern heating zone, the 11 cities belonging to the region also started to take serious action for switching to coal. The efforts of the Chinese government to prevent and control winter haze have continued. Since the APCMAP 2017–2018 was published, the yearly transition targets were introduced to support the transition through APCMAP in the Beijing-Tianjin-Hebei and Surrounding Areas in the Autumn and Winter of 2018–2019 and 2019–2020 and APCMAP in the Fen-Wei Plain Region in the Autumn and Winter of 2018–2019 and 2019–2020. These two documents were combined in 2020; in total, 39 focal cities are intensively working on the transition tasks through APCMAP in the Beijing-Tianjin-Hebei and Surrounding Areas and the Fen-Wei Plain Region in the Autumn and Winter of 2020–2021.

3. Cadre Responsibility and Evaluation System in Chinese Environmental Governance

3.1. The Role of Cadre Responsibility and Evaluation System in Chinese Environmental Policy Implementation

The Chinese central government has been strengthening and maintaining its managerial control over policy implementation through the cadre responsibility and evaluation system, which is built upon the nomenklatura system [15,30,31]. The leading positions in the Party and government listed in the nomenklatura are selected and appointed by the Communist Party of China (CPC). The Party committees also exercise authority over the promotion, removal and transfer of leading cadres. The decisions on promotion, removal, and transfer are made using the cadre responsibility and evaluation system, which evaluates the work performance of the leading cadres [31,32]. Therefore, the system itself distributes political incentives to motivate local leaders who are responsible for implementing policies and measures to carry out the central government's policy priorities.

To assess the work performance of local leaders, performance contracts and targets are used under the cadre responsibility and evaluation system. The performance contracts, known as target responsibility letters, are signed between higher- and lower-level governments (i.e., the central and provincial governments, provincial governments and prefecture-level cities, and prefecture-level cities and counties, counties, and townships). Through the letters, the leaders of lower-level governments pledge to fulfill the targets assigned by higher levels and to take personal responsibility to achieve them [31]. The central government assigns numerical national performance targets, allocates the targets to provinces, and creates a scoring system to weigh the performance. These performance targets are ranked in the priorities of the central government as soft-expected (yuqixing) and hard-binding (yueshuxing) targets in the national five-year plans. The binding hard targets with veto power (yipiao foujue) have the highest priorities; if the leader fails to attain these targets, all their other achievements will lose validity [15,16,19,31,33].

The Chinese environmental policy implementation relied on cadre responsibility and an evaluation system to encourage target accomplishment. The 11th Five-Year Plan for National Economic and Social Development (2006–2010) set the first national environmental binding targets. Environmental targets were included in the previous five-year plans, but they were largely ignored, as evidenced by the SO_2 emissions increasing by 27% during the 10th Five-Year Plan (2001–2005) periods [19]. The 10% reduction target was completely ignored. The Chinese government upgraded the environmental targets from expected to binding status. It also distributed the national SO_2 emission reduction targets of the 11th Five-Year Plan to provincial governments through the National Control Plan for the Total Emission of Major Pollutants during the 11th Five-Year Plan Period in 2006. In addition,

the State Council delivered the Method for Assessing the Total Emissions Reduction of Major Pollutants to announce the "one-vote veto (one strikeout)" system in 2007 [34,35]. Consequently, compliance with the assigned binding targets became the key to performance assessment and evaluation of local cadres. The failure to meet these "veto targets" could negate all positive credits acquired from other cadre performances. Therefore, local cadres who performed well received rewards such as promotion and financial support for future projects [33], but local cadres who failed to meet the targets were penalized by demotion and suspending the review and application for new projects [30].

In addition to SO$_2$, the reduction of PM2.5 had begun to be controlled by the cadre responsibility and evaluation system since 2013. The 12th Five-Year Plan (2011–2015) had presented more detailed targets on environmental and climate change issues. The emission target for NOx, another major air pollutant, has been set, but the PM2.5 concentration reduction targets were omitted. The Chinese government published the APAPPC 2013–2017 to control PM2.5. Provincial Party secretaries and governors of all municipalities and provinces with targets in this document were asked to sign letters of target responsibility for tackling air pollution. Then, the Measures to Evaluate the Implementation of Action Plan on Air Pollution Prevention and Control 2013–2017 was issued, and a scoring system was introduced to evaluate the performance of local officials in the key cities of work listed in the APACCP 2013–2017 [36]. The Measures specified that achieving reduction is a mandatory indicator in the performance assessment of the three key regions mentioned in the APACCP 2013–2017, and Shanxi, Shandong, and Inner Mongolia were also asked to control PM2.5. Later that year, PM2.5 concentration reduction targets were finally added in the 13th Five-Year Plan in 2016. The Chinese government has continuously introduced stronger enforcement measures to ensure implementation and incentivize local cadres to follow the policy preferences of the central government.

3.2. The Cadre Responsibility and Evaluation System and Its Impact on Policy Outcomes

Because environmental policy implementation has been linked to cadre responsibility and evaluation system, environmental issues began to be placed at the top of the policy agenda, with increased responses from the officials. However, questions on its effectiveness have been raised constantly, as the implementation gap remains a key issue in China's environmental governance. Here, the implementation gap can be understood as the difference between the long-term environmental goals of the central government and implementation outcomes at the local level [15,18,37]. In other words, under the Chinese environmental governance, local governments achieve performance targets, but these policy outputs frequently do not extend to positive policy outcomes. The poor incentives and structural shortcomings mentioned in the earlier section have distorted the implementation process for the following reasons.

Firstly, local Chinese cadres tend to adopt a last-minute approach for environmental policy implementation. The central government sets the rules and allocates targets; however, whether its interests or intentions are to improve environmental outcomes is doubtful [15]. More local leaders were promoted because of better economic performance and not environmental protection [38]. In addition, they often face many constraints, such as financial pressure, lack of technology, and limited political capacity to enforce environmental policies. There is significant financial pressure; for example, the installation and operation of pollution removal or reduction equipment require additional investment, but benefits mostly occur in the longer term [16]. Consequently, local governments have not been sufficiently incentivized to prioritize environmental policies to impress their superiors, as their terms in office do not last as long as five years. However, because environmental binding targets must be achieved, efforts to meet the targets are intensified or rushed when the deadline approaches. Because the targets need to be achieved in a limited time, the last-minute response misleads the implementers to manipulate data or take short-sighted action [39]. The damage to public interests at the end year of the 11th Five-Year Plan was due to the misconduct of many localities to achieve environmental and energy targets.

Finally, an emergency note prohibiting short-term electricity cuts and closure of production lines was issued by the NDRC in September 2010 [39]. Unfortunately, the pollution became severely visible from the beginning year of the 12th Five-year Plan in 2011, and many local governments sought to attract outside enterprises to increase GDP so that they could easily improve the energy intensity ratio.

Secondly, the local government cadres tend to play a "numbers game" as the environmental improvements have been monitored and evaluated at the local level. For cadre performance evaluation, environmental data must be accurately and completely collected, reported, and verified. Since the central government decentralized this monitoring process, it has been accused of providing substantial room to local cadres formulating "satisfying data" [19,20,24]. Elevating environmental targets to binding status also leads local officials to be more creative in fabricating and falsifying data, as they do not have incentives to report failures of implementation, which could harm their career and chances for advancement [22]. The local environmental protection bureaus (EPBs), which are responsible for pollution control, environmental monitoring, and ecological conservation, are considered to have the highest authority and responsibility over environmental policy implementation [15]. However, in practice, the local EPBs are closely linked to local governments as the bureaus are run using the local fiscal budget, and the EPB officials are appointed by local leaders. Local fiscal incomes have been mainly raised by the sales and value-added taxes of local enterprises since the 1994 tax reform. Local governments protect them from generating higher tax revenues while not being disturbed by environmental regulations. Therefore, local environmental officials are strongly influenced by and unavoidably protect their local protectionist leaders from being poorly assessed [40]. This trend also extends to the dynamic between central inspectors and local governments. Because the MEP could face significant consequences if the national environmental targets are not met, the central inspectors overlook debatable or non-existent reductions reported by local governments when the national targets seem difficult to achieve [19]. Since 2016, environmental inspections have been centralized. Its influence and effectiveness in combating air pollution will be discussed in a later section.

Finally, Chinese local government officials are not incentivized to surpass the binding targets, and neglect untargeted environmental issues. Failing to meet binding targets could prevent local officials from being promoted or evaluated as excellent; hence, they have strong incentives to meet the targets. However, they are not motivated to surpass targets, as regulations do not clearly mention or offer different reward structures for provinces that fulfill and exceed targets. Therefore, binding environmental targets tend to provide the baseline requirements. For example, the Method for Assessing the Total Emissions of Major Pollutants issued in 2007 directed that provinces that achieved targets would be rewarded and prioritized to receive financial support from the central government for subsequent environmental tasks [34,41]. Similarly, the Measures to Evaluate the Implementation of Action Plan on Air Pollution Prevention and Control 2013–2017 stated that the assessment results would influence financial support for provinces, differentiating between provinces with excellent and incomplete statuses [26]. Again, rewards for provinces that exceeded the targets were not mentioned. Moreover, during interviews with local officials, Genia Kostka revealed that they tend to purposefully fulfill only the minimum requirements to leave room for future targets or not to get higher targets for the next term [22,39]. As the target allocation method is undisclosed, they were worried that performance history could be a possible standard for the next target allocation. Moreover, since the number of environmental and energy obligatory tasks increased from five in the 11th Five-Year Plan to 11 and 16 in the 12th and 13th Five-Year Plans, respectively, untargeted environmental issues and concerns were easily ignored as they would only add "additional work" to local cadres. Hence, even though local leaders had recognized the seriousness of the problem due to particulate matter, they were not seriously considered until the binding targets of PM10 and PM2.5 were listed in the policy plans [22].

4. Methodology and Data

4.1. Case Study: Shanxi Province

Shanxi is a major coal-producing province in China. It was ranked as the best coal-producing province until 2015, when Inner Mongolia achieved the highest rank; however, Shanxi recaptured its former ranking in 2020 [5]. The contribution of Shanxi's coal industry to local GDP was the highest at 32.02% in 2016. Inner Mongolia was placed second, with a contribution of only 18.37% [42]. Shanxi has inevitably been using more coal as it is abundant; coal consumption accounted for 84.6% of the primary energy mix in 2017 [43]. Therefore, compared to the other six municipalities and provinces of the 2 + 26 key cities and the Fen-Wei Plain region, the per capita coal consumption of Shanxi was the highest (Figure 1), which has to be reduced for air pollution control; hence, the province should be encouraged to make the low-carbon transition.
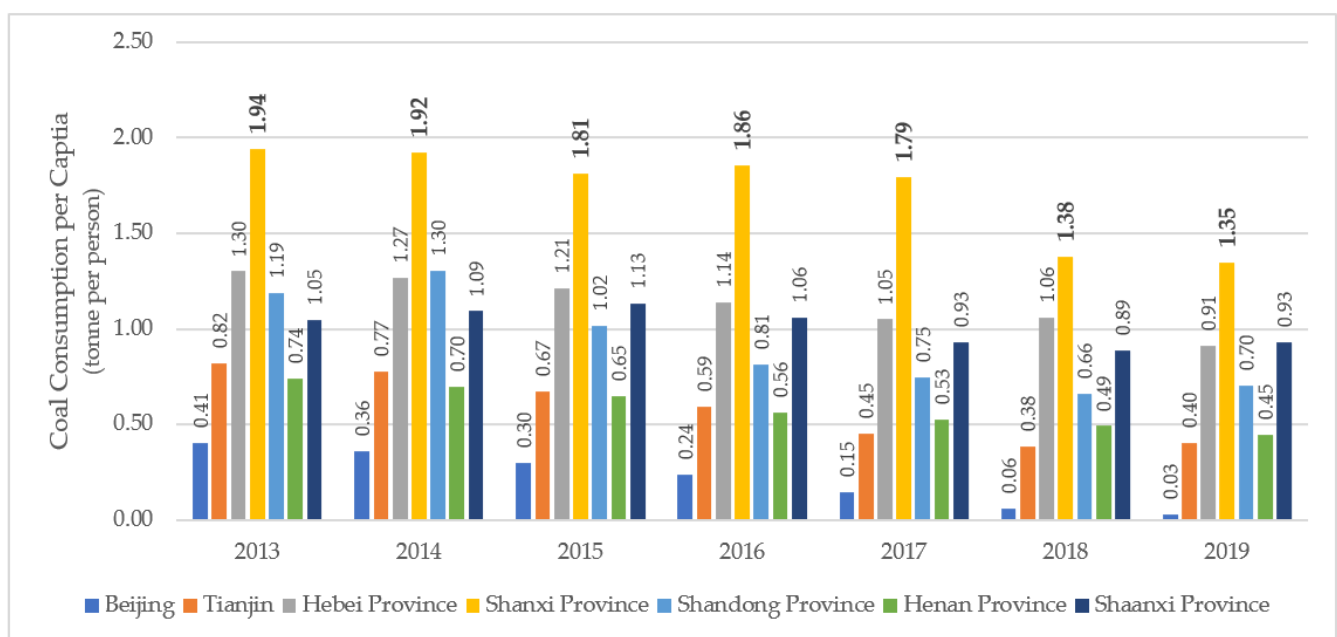

Figure 1. Coal consumption per capita in 7 municipalities and provinces. Source: China Statistical Yearbook 2014–2020, China Energy Statistical Yearbook 2014–2020.

The 2 + 26 key cities and the 11 cities of the Fen-Wei Plain region are the most polluted regions to which the central government has paid more attention. The former received its transition targets in 2017 and the latter in 2018. Therefore, these regions were inspected more intensively than the untargeted regions to ensure their environmental performance. Among the seven municipalities and provinces of the 2 + 26 key cities and the Fen-Wei Plain region, only Shanxi and Henan provinces belong to both groups. However, as was mentioned earlier, Henan province is partly placed in the northern heating zone; hence, Shanxi province is more suitable to examine the impact of the clean heating transition on SO_2 levels.

This study classified the 11 prefecture-level cities of Shanxi into three groups. The four 2 + 26 key cities, Taiyuan, Yangquan, Changzhi, and Jincheng, and four cities of the Fen-Wei Plain region, Jinzhong, Yuncheng, Linfen, and Lüliang, were placed in treatment groups 1 and 2, respectively. The remaining three cities, Datong, Xinzhou, and Shuozhou, which had not received any performance targets from the central government, were placed in the control group (Figure 2).
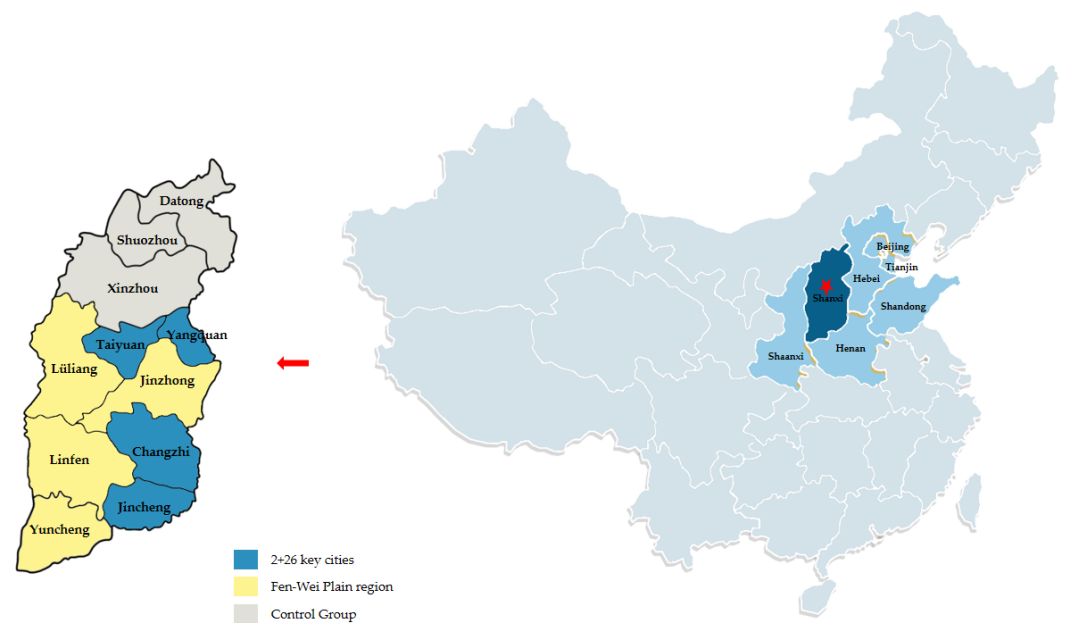
Figure 2. Shanxi province and its three groups.

4.2. Study Design and Data Sources

This study used daily concentrations of SO_2 as the primary assessment index to examine changes in air quality due to policy interventions. Particulate matter is formed when primary pollutants, such as SO_2 and other pollutants, react in the atmosphere. Firstly, SO_2 needs to be controlled in China to reduce PM10 and PM2.5. However, the driving factors of PM2.5 concentrations are not solely limited to coal combustion. Therefore, the SO_2 level is a more appropriate indicator to examine the impact of performance targets on the clean heating transition. SO_2 emission reduction was one of the first national environmental tasks with a binding target set in the 11th Five-Year Plan (2006–2010), and the task continued to the 13th Five-Year Plan (2016–2020). The APCMAP 2017–2018 and TYAP 2018–2020 of Shanxi autonomously added SO_2 concentration reduction targets instead of emission reduction targets in the Five-Year Plans [44,45]. The APCMAP 2017–2018 of Shanxi set a target for reducing the SO_2 concentration by 40% compared to the same period of the previous year, and TYAP 2018–2020 assigned a 50% reduction target compared to the levels in 2015.

SO_2 is a key gaseous tracer for coal consumption. Because heating is the most significant source of additional air pollution in winter and coal is the main energy source for heating, approximately 83% in northern China, considerable SO_2 reductions would be achieved through the clean heating transition [46]. Meng et. al proposed that if "there were no significant changes in production and emissions of industry, power generation and other sectors, the extra emissions caused by heating in winter can be determined by subtracting the average constrained emissions" in winter [47]. This assumed that the majority of additional SO_2 concentrations during the heating seasons were due to heating. For the three years prior to 2017, when the performance targets on clean heating transition were assigned, the difference in SO_2 concentrations between the heating and non-heating seasons were different by as much as 3.85 times in Taiyuan, the capital city of Shanxi. For other pollutants, the differences between the heating and non-heating seasons were 1.77, 1.37, 1.72, and 1.26, for PM2.5, PM10, CO, and NO2, respectively. This again highlights the suitability of SO_2 as an indicator.

The study period was from January 2015 to March 2021. Generally, the central heating season runs for four months in North China, and 5–7 months in Northeast and Northwest China from October to April based on local temperatures. The 11 cities of Shanxi also have different heating periods based on their winter temperatures. The legal heating periods for Changzhi, Jincheng, Yuncheng, and Linfen runs from November 15 to March 15, Taiyuan,

Yangquan, Jinzhong, Lüliang, and Xinzhou from November 1 to March 31, and Datong and Shuozhou from October 25 to April 10. The heating periods differ between 4 months to 5 months, but the duration is also adjusted if the temperature drops earlier or if the low temperature continues even after the legal heating periods. In addition, individual heating in rural areas does not follow legal heating periods. Accordingly, in this study, we take the heating season from October to March as it is used in the Action Plans for Comprehensive Management of Air Pollution in the Beijing-Tianjin-Hebei and Surrounding Areas in the Autumn and Winter. Because the targets for clean heating transition were first put in February 2017 to treatment group 1 and in October 2018 to treatment group 2, SO_2 concentration data for 2015 and 2016 were used to examine changes before and after the targets were assigned.

The air pollutant data were acquired from the website of Chinese AQIstudy, which provides daily average levels of air pollutants from 367 Chinese cities. Weather data were obtained from the Chinese National Meteorological Information Center under the China Meteorological Administration.

4.3. Statistical Analysis

This study used a difference-in-differences (DID) approach to estimate the impact of the performance target on ambient SO_2 levels in Shanxi province. The DID approach is a widely used quasi-experimental design for the study of many policy questions, and it estimates the causal effect of policy interventions by comparing the change in outcome between treated and untreated controls before and after treatment. The DID model used in this study is represented by the following equations:

$$Y_{ct} = \beta_0 + \beta_1 T + \beta_2 D_c + \beta_3 (T \times D_c) + \beta_4 f(Z_{ct}) + \varepsilon_{ct} \qquad (1)$$

where Y_{ct} is the daily average SO_2 concentration level for city c at time t, which was monitored before (T = 0) and after (T = 1) the treatment (D_c). β_3 is the coefficient of interest and estimates the average treatment effect on the treated samples. Z_{ct} includes a quadratic functional form of meteorological variables, temperature and humidity, and ε_{ct} represents residual errors.

$$\beta_3 = (E\,[Y_{ct}\,|c = \text{treatment},\ t = 1]\ -\ E\,[Y_{ct}\,|c = \text{treatment},\ t = 0]) - (E\,[Y_{ct}\,|c = \text{control},\ t = 1] \\ -\ E\,[Y_{ct}|c = \text{control},\ t = 0]) \qquad (2)$$

This DID estimator compares the changes in SO_2 levels in the cities examined, to changes in SO_2 levels in control cities in Shanxi.

4.4. Document Analysis

This study also uses the document analysis method to examine the implementation process of a clean heating transition. It particularly focuses on the question of how the transition tasks were centralized, how Shanxi province responds or interprets the centralized tasks, why Shanxi has responded with an overzealous transition, how and what has supported the continuous transition efforts even though a gas shortage had occurred, and what the policy outcomes of inadequate heating supply are. To answer these questions, central and local policy documents and the statements of elite authorities were carefully examined. Moreover, the messages regarding clean heating transition written by the residents of Shanxi on the bulletin boards of Development and Reform Committee (DRC) of Shanxi were reviewed to understand the actual situation (at least partially), alongside examining environmental inspection reports that thoroughly describe the problems caused by a clean heating transition.

5. Results

5.1. Air Quality Improvement

Table 1 shows the regression results for Equation (1), which estimates the effect of air pollution controls on SO_2 levels. Column (1) begins by including only treatment assignment status (D), treatment period (T), and the DID estimator, which is defined as the interaction term of the two (T × D). The coefficient of interest β_3 is −13.709, which is statistically significant, indicating that the pollution controls reduced SO_2 concentration by approximately 14 μg/m^3 (equivalent to a decrease of 21%), on average. The city-fixed effects are included to control for unobserved heterogeneity across the cities in column (2), and the results are robust.

Table 1. Baseline regression results.

	(1)	(2)	(3)	(4)
T	−29.571 *** (1.167)	−29.571 *** (1.161)	−27.079 *** (1.002)	−1.962 (1.199)
D	6.122 *** (1.062)		10.112 *** (0.913)	7.376 *** (0.812)
T × D	−13.709 *** (1.353)	−13.815 *** (1.355)	−14.218 *** (1.162)	−15.700 *** (0.960)
Heating season			47.648 *** (0.514)	15.786 *** (1.166)
Temperature				0.589 *** (0.069)
Temperature^2				−0.027 *** (0.003)
Humidity				0.705 *** (0.065)
Humidity^2				−0.009 *** (0.001)
Wind speed				−10.214 *** (0.249)
City fixed effects	No	Yes	No	No
R^2	0.161	0.157	0.382	0.600
Observation	24,110	24,110	24,110	24,106

*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$.

In column (3), the heating season is included to control for coal-fired heating during winter. The heating season is typically between October to March of the following year, during which time the ambient air pollution levels are at their highest. The result in column (3) suggests that the SO_2 level is 47.65 μg/m^3 (approximately 205%) higher during the heating season compared to other months. Column (4) includes weather controls such as wind speed and quadratic forms of temperature and relative humidity. The results show that the clean heating transition reduced SO_2 levels by approximately 16 μg/m^3, (equivalent to a decrease of 23.74%), providing empirical evidence for air pollution reduction due to the transition to clean energy.

Furthermore, the treatment group is now split into two groups: the 2 + 26 key cities and the Fen-Wei Plain region in order to examine the effect of performance targeting. Table 2 shows the heterogeneous treatment effects of the two groups. D1 and D2 represent the Fen-Wei Plain region and the 2 + 26 key cities, respectively. In columns (1)–(4), we find a greater reduction in SO_2 levels in the cities of the Fen-Wei Plain than in the 2 + 26 key cities, indicating that targeting achievement goals did not result in better outcomes. We also tested whether the treatment effects are significantly different from each other, and the large F statistic suggests that we can reject the equality hypothesis at the 1% level.

Table 3 shows the regression results for the heating seasons only, and the indicator for the heating season is now omitted from the regressions. In all model specifications, the clean heating transition led to a significant reduction in SO_2 levels in winter, and the larger impacts were found in the Fen-Wei Plain region.

Table 2. Regression results: Two treatment groups.

	(1)	(2)	(3)	(4)
T	−29.571 ***	−29.571 ***	−27.077 ***	3.688 ***
	(1.167)	(1.160)	(1.002)	(1.258)
D1	6.675 ***		11.123 ***	12.922 ***
	(1.132)		(0.973)	(0.901)
D2	5.216 ***		8.461 ***	1.950 **
	(1.240)		(1.065)	(0.898)
T × D1	−15.562 ***	−15.562 ***	−16.632 ***	−19.498 ***
	(1.523)	(1.515)	(1.308)	(1.126)
T × D2	−11.959 ***	−11.957 ***	−11.653 ***	−11.008 ***
	(1.543)	(1.535)	(1.325)	(1.064)
Heating season			47.674 ***	15.574 ***
			(0.514)	(1.161)
Temperature				0.573 ***
				(0.069)
Temperature^2				−0.028 ***
				(0.003)
Humidity				0.649 ***
				(0.065)
Humidity^2				−0.008 ***
				(0.001)
Wind speed				−10.254 ***
				(0.248)
City fixed effect	No	Yes	No	No
F statistic (*p*-value)	6.55 (0.0105)	6.63 (0.0100)	16.97 (0.0000)	65.14 (0.0000)
R^2	0.162	0.157	0.382	0.604
Observation	24,110	24,110	24,110	24,106

*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$.

Table 3. Regression results: Heating season only.

	(1)	(2)	(3)
T	−46.569 ***	−46.603 ***	8.457 ***
	(2.075)	(2.037)	(2.861)
D1	28.561 ***		27.996 ***
	(2.044)		(2.004)
D2	19.688 ***		4.017 **
	(2.234)		(2.036)
T × D1	−36.062 ***	−36.028 ***	−39.017 ***
	(2.845)	(2.793)	(2.564)
T × D2	−25.948 ***	−25.992 ***	−22.314 ***
	(2.851)	(2.799)	(2.414)
Temperature			0.313 **
			(0.125)
Temperature^2			−0.055 ***
			(0.010)
Humidity			0.994 ***
			(0.157)
Humidity^2			−0.012 ***
			(0.001)
Wind speed			−16.321 ***
			(0.507)
City fixed effect	No	Yes	No
F statistic (*p*-value)	13.44 (0.0002)	6.63 (0.0100)	16.97 (0.0000)
R^2	0.299	0.288	0.521
Observation	9470	9470	9467

*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$.

5.2. Rapid and Large-Scale Transition

As the APACCP 2013–2017 entered a critical stage, the central government responded by instituting more detailed measures and increasing target levels to induce local implementers to work in the interests of the central authorities. When local governments appeared to face difficulties following the preferences of the center, the central government routinely reacted in an opposing manner [48], so the ad hoc campaign-style implementation was repeated at the end year of APACCP 2013–2017. In addition, as the authorities sent clearer messages on the importance of environmental protection and the environmental inspection system was strengthened by the central leadership, the tasks of the clean heating transition were highly politicized.

In February 2017, the Chinese government introduced the 2 + 26 key cities as the air pollution transmission channel, and mandated each city to complete replacing coal with gas or electricity for a minimum of 0.05 million to a maximum of 0.01 million households by the end of October 2017 through WPACCP 2017. The total ranged from a minimum of 1.4 million to a maximum of 2.8 million households. Soon after August of the same year, the APCMAP 2017–2018 was issued with upgraded targets and detailed requirements for clean heating transition. The 2 + 26 key cities were asked to complete the relevant transformation in a total of 3.55 million households by October 2017. Unlike the WPACCP 2017, the APCMAP 2017–2018 assigned differential targets to the 28 cities. Consequently, the transition targets in total were increased from 0.75 million to as much as 2.15 million households in 6 months, but the deadline to complete the transition was only two months for all the 2 + 26 key cities.

The top-tier authorities, highlighting the significance of the clean heating transition and air pollution control, provided stronger incentives to vigorously promote coal-to-gas and coal-to-electricity projects. At the 14th meeting of the Central Financial and Economic Leading Group in October 2017, the importance of the clean heating transition in preventing winter haze and ensuring a warm winter for the people was highlighted by President Xi Jinping [49]. At the 19th National Congress of the CPC, the President stressed pollution prevention and control as one of the "three tough battles" to be fought and won by 2020 to "finish building a moderately prosperous society in all respects and achieve the first centenary goal" [50]. President Xi highlighted the (i.e., environmental protection, green and ecosystem) more than the economy in his speech; each was mentioned 89 and 70 times, respectively. This was a reversal compared to the speech delivered by former President Hu Jintao, who used 104 and 74 words related to the economy and environment respectively at the CPC 18th National Congress in 2012 [51]. Additionally, at the National People's Congress held in March 2017, Premier Li Keqiang mentioned that the prevalence of clean winter heating, through the replacement of coal with gas or electricity, should be more than 3 million households [52]. The announcement by Premier Li was made only a few days after the WPACCP 2017 was issued with the transition target from a minimum of 1.4 to a maximum of 2.8 million households. As he listed the clean heating transition tasks firstly to reduce coal burning and environmental protection, coal replacement became the center of environmental issues.

The new central environmental inspection system has also clearly specified the attitude of the central government towards environmental protection. To address the lack of accountability and control over local governments, the central government under Xi Jinping established the central inspection team with support from the two most powerful CCP institutions: the Organization Department and the Central Commission for Discipline Inspection [40,53]. The Organization Department is responsible for party personnel assignments, so it determines the general regulations of the cadre performance evaluation system and assesses cadre performance accordingly [15]. The Central Commission for Discipline Inspection is the most powerful anti-corruption organ in China. The process was highly politicized because the officials from the two organs and retired ministry officials joined the inspection team and the focus of the inspection was adjusted to the highest-ranking local party and government leaders instead of polluting enterprises. Under this strengthened

control system, any local leader who was observed to be involved in misconduct or as inattentive to environmental protection, could face immediate demotion or removal from the positions and face possible corruption investigation regarding protectionist behavior [40].

Alongside the central environmental inspection, the MEP organized another inspection system under the Enhanced Supervision Plan for Air Pollution Prevention and Control for the Beijing-Tianjin-Hebei and Surrounding Areas in 2017–2018. For the clean heating transition, the 11th to 25th rounds of the inspection were systemically assigned for APCMAP 2017–2018. The inspection was divided into two stages. The first stage was to ensure and urge all the listed and time-limited tasks to be completed at this stage, so the inspection teams were dispatched to each of the 2 + 26 key cities every month from 1st September to 9th November,2017. The second stage was conducted using "two-way feedback" inspection system from November 10, 2017 to March 29, 2018 [54]. To improve the efficiency of regulation and address the problem of inadequate enforcement, the MEP planned to use satellite remote sensing and monitor heavily polluted areas. The 2 + 26 key cities were divided into 3 km $\times$ 3 km grids, and 3600 highly polluted grids were selected for intensive monitoring among 36,783 grids [55]. Once a high concentration of air pollution was detected by the sensor, the inspection team and the environmental protection department of each city conducted investigations, and the local governments belonging to the particular grids were required to report on the reasons and problems of the pollutant increase within the same day when it was detected. The investigations were carried out until the grids were significantly improved. Through strengthening of the inspection systems, the central government gave clear signals to local governments to prioritize environmental protection, and Shanxi responded by exceeding the planned targets.

In addition to these strong political pressures, the wave of dismissals of local leaders who had failed to reach environmental targets during the 12th Five-Year Plan periods had increased the fear of failure, which could undeniably damage their careers [56]. In addition, clean heating conversion projects could increase the employment rate, which has always been regarded as a strategic task for the political and performance legitimacy of the CPC. According to a report, job-seeking day laborers were employed at the construction sites because infrastructure buildings and low-carbon equipment installation for clean heating required an intensive workforce. Moreover, coal switching projects could induce immediate work performance. If they use less coal, especially scattered coal for individual heating, pollutant emissions can be reduced instantly. Local leaders did not have to hesitate; instead, they were motivated to respond by reinforcing actions.

The Shanxi province administration perceived changes in the interests of the central government in environmental protection, and responded overzealously on transition tasks. Shanxi received a transition target of 0.39 million households from the central government in 2017. However, the provincial government assigned transition targets to the rest of its seven centrally untargeted, prefecture-level cities through the APCMAP 2017–2018 of the Shanxi province. Therefore, the total transition target set in Shanxi was 1.014 million households which was 2.6 times higher than what the central government had assigned for the province (Table 4). As a result, 1.13 million households completed the transition in 2017. This means that the performance target assigned by the central government was surpassed by nearly 190%. Particularly, among the 1.13 million households, only 0.42 million households completed the coal-to-gas or coal-to-electricity transitions in the targeted, 2 + 26 key cities group [57]. This indicates that the transition efforts were not concentrated in the 2 + 26 key cities group, but were fairly distributed in untargeted cities, as was planned by Shanxi provincial government (Table 4).

Table 4. Shanxi province's clean heating transition targets at the three levels of government.

	Central Government Plan		Provincial Government Plan	Prefecture-Level City Government Plan
		(Unit: Million Households)		
Taiyuan		0.112	0.112	0.134
Yangquan	0.390	0.056	0.058	0.058
Changzhi		0.118	0.118	0.118
Jincheng		0.112	0.111	0.100
Jinzhong			0.100	0.111
Yuncheng			0.063	0.064
Linfen			0.191	0.100
Lüliang			0.100	0.102
Datong			0.053	0.053
Xinzhou			0.059	0.059
Shuozhou			0.050	0.050
Total	0.390	0.398	1.014	0.948

Source: Central Government Plan [28], Provincial Government Plan [44], Prefecture-level City Government Plan [58–68].

6. Discussion

6.1. Clean Winter in Shanxi Province

The SO_2 concentrations in Shanxi were continuously reduced both annually and every heating season, and have not reverted to the previous levels since the performance targets for clean heating transition were imposed in 2017. The annual mean of SO_2 concentrations in Shanxi fell under China's first-level concentration limit of 20 $\mu g/m^3$, and the maximum monthly concentrations also fell sharply to 40 $\mu g/m^3$ in 2020 (Table 5). Therefore, the mean concentrations of SO_2 during October 2020 to March 2021 were only 1.8 times that of those in spring and summer (April 2020–September 2020) of the same year (Table 6).

Compared to 2016, when the annual mean concentrations of SO_2 were 60 $\mu g/m^3$ and the mean concentrations in autumn and winter were 4.0 times higher than those in spring and summer (28 $\mu g/m^3$–113 $\mu g/m^3$), the annual and heating season's SO_2 concentrations in 2020 were reduced by one-third (60 $\mu g/m^3$–18 $\mu g/m^3$) and controlled by 81% (113 $\mu g/m^3$–22 $\mu g/m^3$). As a result, the targets set for Shanxi from the APCMAP 2017–2018 and the TYAP 2018–2020 were both met. The SO_2 concentration in Shanxi during the 2017–2018 heating season was 56 $\mu g/m^3$. As it was reduced by 50% from 113 $\mu g/m^3$ in the previous heating season, it surpassed the 40% reduction target. The TAYP 2018–2020 target of 50% reduction by 2020 compared to 2015 was 18 $\mu g/m^3$ from 56 $\mu g/m^3$. This was reduced by 68% (Table 6).

The reduction in SO_2 concentrations in the Fen-Wei Plain region was greater than that in the 2 + 26 key cities during the study period. SO_2 concentrations in all three groups declined further during the first assessment of the heating season. In particular, the SO_2 concentration in the 2 + 26 key cities decreased the most. SO_2 concentrations in the other two regions (Fen-Wei Plain region and control group), for which the central government did not specify a target amount, also reduced significantly between October 2017 to March 2018 (Table 6). In the subsequent heating seasons (October 2018–March 2019 and October 2019–March 2020), the SO_2 levels in the Fen-Wei Plain showed a continuous decrease and were more significant than those in the 2 + 26 key cities. A higher transition goal was set in the Fen-Wei Plain group than in the 2 + 26 key cities since 2018; this might have resulted in a greater reduction in SO_2 concentration in the Fen-Wei group (Figure 3).

Table 5. The annual mean and maximum monthly concentrations of SO$_2$ in Shanxi province.

	2 + 26 Key Cities Group (4)				Fen-Wei Plain Group (4)				Control Group (3)			
(Unit: μg/m^3)												
	Taiyuan	Yangquan	Changzhi	Jincheng	Jinzhong	Yuncheng	Linfen	Lüliang	Datong	Xinzhou	Shuozhou	Average
2015	69	59	49	56	72	54	64	69	42	57	76	56
2015 *	179	126	133	115	177	130	260	150	80	114	187	150
2016	68	62	61	70	88	66	83	63	48	49	67	60
2016 *	186	118	164	139	263	154	351	191	130	120	154	179
2017	55	50	43	48	84	52	79	69	45	49	47	52
2017 *	163	115	145	99	249	113	311	184	101	116	143	158
2018	27	30	20	23	34	27	43	37	29	31	33	28
2018 *	63	62	48	47	91	83	116	91	50	66	70	72
2019	22	23	16	16	26	15	28	29	30	29	31	22
2019 *	58	65	41	40	68	41	107	91	65	65	92	67
2020	17	20	17	13	20	13	19	18	30	20	26	18
2020 *	33	37	33	24	44	21	54	31	52	40	76	40

Source: Calculated by authors using data from AQIstudy. Year with * represents maximum monthly value in each year. Numbers in parentheses indicate number of cities belong each group.

Table 6. Shanxi province's SO$_2$ mean concentrations: Spring and summer vs. autumn and winter.

	2 + 26 Key Cities Group (4)				Fen-Wei Plain Group (4)				Control Group (3)			
(Unit: μg/m^3)												
	Taiyuan	Yangquan	Changzhi	Jincheng	Jinzhong	Yuncheng	Linfen	Lüliang	Datong	Xinzhou	Shuozhou	Average
April 2015–September 2015	28	32	28	39	36	35	24	41	24	37	35	30
October 2015–March 2016	91	94	97	93	101	102	53	75	63	62	109	85
April 2016–September 2016	29	34	17	37	37	34	35	27	24	32	32	28
October 2016–March 2017	121	84	101	85	184	87	196	127	81	85	94	113
April 2017–September 2017	25	28	16	29	35	26	34	30	26	28	19	25
October 2017–March 2018	52	54	33	43	75	61	79	74	42	52	52	56
April 2018–September 2018	13	17	10	15	14	13	20	17	18	19	15	14
October 2018–March 2019	35	37	26	25	43	25	51	52	42	42	53	39
April 2019–September 2019	13	14	11	12	13	9	14	17	20	22	16	13
October 2019–March 2020	25	23	19	17	30	16	27	25	37	29	41	26
April 2020–September 2020	11	14	13	10	11	10	11	15	21	16	15	12
October 2020–March 2021	21	26	20	15	29	15	20	19	35	20	24	22

Source: Calculated by authors using data from AQIstudy. Numbers in parentheses indicate number of cities belong each group.
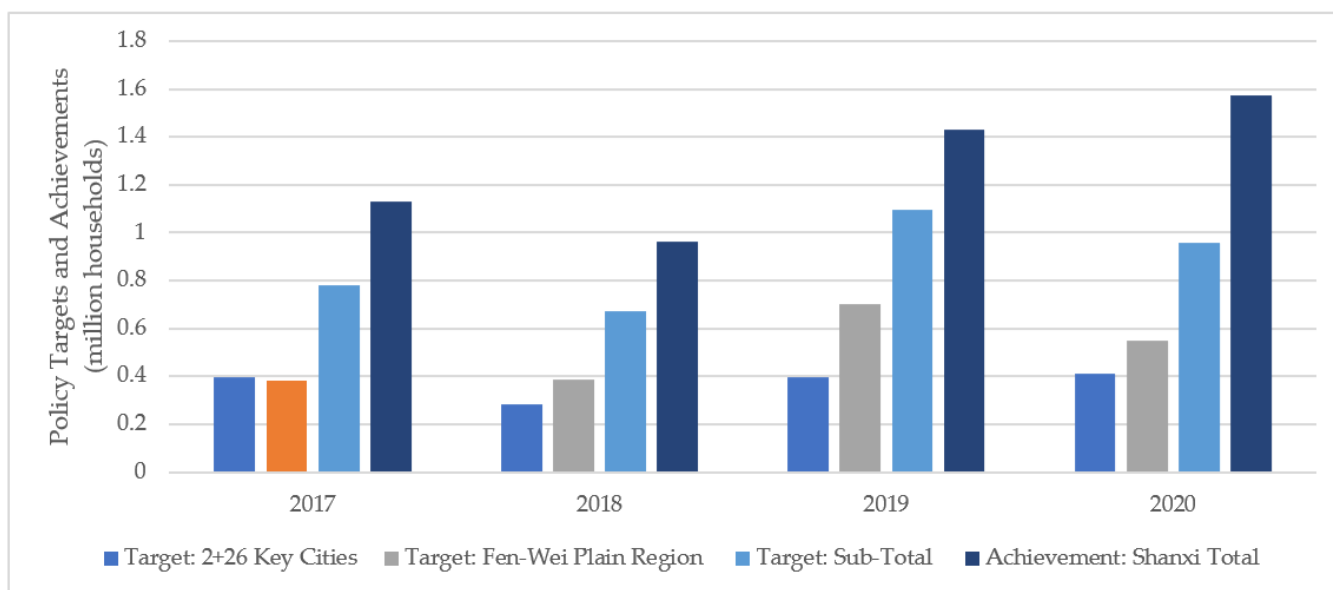
Figure 3. Policy targets and transition achievements in Shanxi. Source: 2 + 26 key cities group [28,69–71]; Fen-Wei Plain region group [62–65,71–73] The Fen-Wei Plain region group's 2017 target data is from each prefecture-level city's APCMAP 2017–2018. The unit is one million households.

The groups of the 2 + 26 key cities and the Fen-Wei Plain region both exceeded the transition coverage rate set by the central government. The Clean Winter Heating Plan in Northern China (2017–2021) set targets for clean heating rates to reach 50% in northern China by 2019 and 70% by 2021. However, higher targets were assigned to the 2 + 26 key cities: 90% and above should be attained in urban areas, 70% in urban fringe areas, and 40% in rural areas by 2019. Furthermore, the transition rates should be 100%, 80%, and 60% by 2021. However, all of the 11 urban cities in Shanxi already attained 98.81% of transition coverage rate, and its urban fringe areas also achieved 86.46% by 2018. The total coverage rate in the rural areas of Shanxi reached only 31.59% in 2018, but rural areas in the 2 + 26 key cities and the Fen-Wei Plain region was 40.96%, so these two regions were ahead of government plans in 2018 (Table 7). However, this unexpected excess disrupted the natural gas supply and forced people to endure cold winters.

Table 7. 2018 Shanxi province's 11 cities clean heating coverage rate.

	Urban Areas	Urban Fringe Areas	Rural Areas	Total
Taiyuan	100%	97.81%	71.98%	96.86%
Yangquan	100%	84%	37%	76.61%
Changzhi	100%	94%	31%	69.45%
Jincheng	96.10%	92.20%	35.98%	57.13%
Jinzhong	100%	88.25%	29.36%	70.86%
Yuncheng	100%	82.77%	49.13%	71.93%
Linfen	96.40%	91.16%	43.81%	70.48%
Lüliang	100%	98.37%	29.42%	74.67%
Datong	93.82%	59.25%	11.28%	50.01%
Xinzhou	94.11%	81.53%	9.67%	59.93%
Shuozhou	99.90%	85.71%	6.32%	57.19%
Total	98.81%	86.46%	31.59%	71.75%

Source: Investigation report on clean heating work [74].

The central government had slowed the clean heating transition through emergency measures because the gas shortages prevented sufficient heating; however, the efforts towards the clean heating transition were not retreated after little adjustment in 2018.

This study finds that the following two factors supported continuous transition efforts: firstly, after the end of APACCP 2013–2017, the Chinese government continuously took serious air pollution control and prevention by issuing the TYAP 2018–2020. However, after experiencing the disastrous social consequences of not securing winter heating for residents, the central government did not include clean heating transition targets in the TYAP 2018–2020 and also did not assign the targets for the 2 + 26 key cities and the Fen-Wei Plain region through the APCMAP. Instead, local governments set transition targets that have been included in the annual APCMAP since 2018. Nevertheless, Vice-premier, Han Zheng who is the leader of the Leading Small Group for APACCP in the Beijing-Tianjin-Hebei and Surrounding Areas and the Ministers of MEE, on a variety of occasions, have reiterated that President Xi attaches great importance to clean heating in winter. In addition, the 2 + 26 key cities and the Fen-Wei Plain region have been centered on the central environmental inspection. Therefore, the transition efforts did not lose its intensity, and the air quality could continue to improve.

Secondly, the Chinese government did not modify the competitive funds that incentivized local governments to continue the fast transition. In 2017, the Ministry of Finance (MOF), MEP, Ministry of Housing and Urban-Rural Development (MHURD), and National Energy Agency (NEA) created a government subsidy policy for clean heating transition, but it was announced that it would be effective only for three years. Three batches of 43 cities were selected to receive the competitive funds for three years. Twelve cities were selected in the first year, 2017. In 2018, 23 more cities began to be funded. Eight cities were added in 2019. All cities in the 2 + 26 key cities and the Fen-Wei Plain region, except Beijing, received this special fund, but the amounts were different based on levels of cities. It proposed that municipalities, provincial capital cities, and prefecture-level cities of the 2 + 26 key cities must be granted 1 billion CNY, 0.7 billion CNY, and 0.5 billion CNY respectively, and cities in Fen-Wei Plain were to receive 0.3 billion CNY regardless of its type [75,76].

The local governments had to achieve a high rate of transition, while funds from the central government supported them. Otherwise, more financial pressure would be imposed. Even though the central government reversed the 'coal ban' attitude for heating systems in December 2017, the local government aimed for a clean heating transition as the special funds were continuously provided. Therefore, the transition efforts were continued in Shanxi as evidenced by the complete transition of 1.13 million, 0.962 million, and 1.43 million households in 2017, 2018, and 2019, respectively [77–79]. According to Shanxi province clean heating work leading group in January 2021, the province completed a total of 5.0945 million clean heating transitions from 2017 to 2020, and 1.5745 million households completed the coal switch in 2020. Consequently, even though the clean heating coverage of the province had already reached more than 70% in 2018 (Table 7), Shanxi had continuously put radical efforts on clean heating transition as the coverage rate reached more than 80% in 2020 [80].

6.2. Cold Winter in Shanxi Province

The rapid and massive clean heating transition cleaned the air, but it failed to secure sufficient heating for Shanxi residents. As a result, Shanxi residents had to endure cold winters, and the central government had to reverse its ambitious plans for coal ban and promoting gas plants. This undermined the energy transition efforts. Firstly, Shanxi residents had to spend cold winters because severe gas shortages and inadequate infrastructure prevented sufficient winter heating. Even though the Shanxi DRC limited gas supplies for the non-residential sectors including industry, commerce, hotels, and offices, it was frequently reported that the gas was often cut off, supplied only a few hours daily, or not restored for longer than 24 h due to a supply shortage [81–83].

Throughout "looking back (huitoukan)" Rectification Plan of Shanxi on the central and the MEE's inspection, the problems of low gas flow, pipe installation for the last meter, and insufficient subsides that hindered the transition process were exposed. During

2017–2018, 0.8859 million households completed the coal-to-gas switch in Shanxi, but only 0.6133 million households could receive gas. Therefore, the overall rate of gas flow was 70%, but there were wide variations among the cities. The rates of gas flow in the cities of Yuncheng (Fen-Wei Plain region), Datong (control group), and Shuozhou (control group) were only 20.3%, 3.1%, and 44.8%, respectively. Due to uneven subsidy standards in Yangquan (2 + 26 key cities), it was reported that some counties inevitably went back to coal heating even though they were connected to pipelines. Moreover, it revealed that only one of the 24 gas companies in Changzhi city (2 + 26 key cities) received government subsidies. The remaining 23 gas companies were unable to sell gas to the residents at a high market price, so they had to endure difficult business conditions until subsides were provided by the central governments [84].

The DRC consultation bulletin boards of Shanxi contained complaints and questions about the last meter pipes, improperly distributed subsides, and high costs of heating from residents all over Shanxi, but especially from Changzhi, Linfen, and Jinzhong. Bulletin boards cannot represent the overall situation, but they have hinted at the partial ambiance of the transition process. Many criticized the pipe networks laid out at the door of their houses, but only those who paid for the installation fees for the last meter pipes could be connected to pipelines and were supplied gas for heating. Others even complained that they were threatened to pay for the installation as early possible and were informed that the price would be higher next year. Although the Shanxi provincial government issued a prohibition on charging construction and installation fees to residents at the end of October 2017, the brutality of the concerned companies continued at least until 2019, when the complaints of the residents were found on the bulletin board [85].

Secondly, the central government urgently revised the clean heating transition measures to address inadequate heating supply and reversed its ambitious plans for energy transition. On the official starting day (November 15, 2017) of central heating in northern China, the NDRC pledged an overall affluent gas supply for the 2017–2018 heating season. Its confidence in smooth and sound gas supply was disregarded 20 days later when the NDRC, NEA, MHURD, and MEP issued emergency measures to secure gas supply and demanded that the coal switch should be pursued once natural gas supply is secured [86]. The emergency measures included an increase in domestic production and LNG imports, diverting natural gas for industrial and power generation to residential use, and transferring more gas from the southern region to the northern heating zone [56]. Consequently, a study found that pollution was highly likely to be transferred to the south as they had to use more coal to replace gas [9].

The outcomes of the APACCP 2013–2017 not only caused gas shortages but also changed the government's attitude towards gas deployment. The NDRC issued two documents on gas deployment during the 13th Five-Year Plan period (2016–2020). The 13th Five Year Plan for Natural Gas Development set the proportion of natural gas in the primary energy consumption structure to attain 8.3–10% and 110 GW of gas-fired generation capacity by 2020. The Opinions on Speeding up Natural Gas Utilization documents the upgradation in the share of natural gas in primary energy consumption to 10%. - To increase gas consumption, both stressed the need to develop gas peaking plants, combined heat and power plants, and promote gas plants to supplement renewable production. Since the central governments reversed tones in the policies, the driving force on the promoting gas plants immediately faded away as they only asked for the development of gas peaking plants and limited new combined heat and power plants in plans and measures on air pollution and clean heating transitions such as the TYAP 2018–2020 and the APCMAP 2018–2019 issued in later years [87]. Moreover, Premier Li Keqiang reiterated at the 2019 National Energy Commission Meeting that the provinces should utilize coal, gas, or electricity according to local conditions to ensure winter heating supply. This was in parallel to previous emergency measures that cautioned against a "one-size fits all" approach on the clean heating transition to slow down the coal to gas or electricity

conversion. In conclusion, the proportion of natural gas and capacity of coal-fired plants was recorded at only 8.4% and 98 GW at the end of 2020, falling short of targets [5].

7. Conclusions

Despite the implementation of the APACCP 2013–2017, the red alerts declared in December 2015 and December 2016 in Beijing represented the severity of air quality problems in winter. As a result, heating started to receive special attention as a major contributor to air pollution in winter, and President Xi Jinping emphasized the importance of a clean heating transition in December 2016. In 2017, the deadline year for the APACCP 2013–2017, President Xi and Premier Li reiterated the importance of environmental protection, a series of measures targeting the clean heating transition were enhanced, and environmental inspection was strengthened by central leadership. Therefore, the clean heating transition tasks were highly centralized.

Since the Chinese government has assigned performance targets to environmental and energy concerns under the cadre responsibility and evaluation system to enhance policy implementation, questions on the effectiveness of target-based implementation have been centered on studies of China's environmental governance. Because environmental performance had been added to the cadre evaluation criteria, theoretically, the cadre responsibility and evaluation system would have incentivized local cadres and officials to prioritize environmental policies. However, the existing literature underlines that the target-based approach creates an implementation gap due to poor incentives and structural shortcomings. Therefore, these studies eventually claim that the central government should have a clearer intention of environmental protection and an enhanced inspection system to narrow the gap and successfully achieve the intended goals.

This study sought to contribute to the lack of empirical evidence on the impact of the recentralized governance on environmental performance by examining the implementation of a clean heating transition. It investigated the impact of a centralized clean heating transition for SO_2 in Shanxi Province from January 2015 to March 2021. This study showed that the SO_2 concentration in Shanxi increased until 2016, then sharply decreased in 2017 when the clean heating transition was vigorously promoted. The clean heating transition led to a significant reduction in SO_2 levels in winter, and larger impacts were found in the Fen-Wei Plain region. It is noteworthy that the difference in SO_2 concentrations between the heating and non-heating seasons in Shanxi had decreased from four times in 2016 to 1.8 times in 2020, and the contribution of the clean heating transition must have been significant. It continued to decrease and attained the national level 1 of the annual mean SO_2 concentration of 20 μg/m^3 in 2020. This study showed that the annual target of air pollution reduction and clean heating transition through APCMAP and three-year competitive funds have supported the transition efforts continuously. Therefore, it is understood that the SO_2 concentration of Shanxi had a greater effect over the past four years (2017–2020), but not from 2013 when the APACCP 2013–2017 began. Moreover, it can be evaluated that the SO_2 concentration reduction effort was successful based on the fact that the SO_2 reduction target was exempted from the 14th Five-year Plan while it had been specified throughout the last 15 years, from the 11th Five-year Plan to the 13th Five-Year Plan.

The administration of Shanxi province perceived changes in the tone and interest of the central government towards environmental protection and invested overzealously on transition tasks. The central government assigned a transition target of 0.39 million households in 2017. However, the provincial government assigned transition targets to the rest of its centrally untargeted cities and completed the transition in a total of 1.13 million households. It surpassed the transition target assigned by the central government by nearly 190%. Interestingly, only 0.42 million households completed the transition in the 2 + 26 key cities, indicating that the transition efforts were fairly distributed in Shanxi as was planned. Further investigation is required to investigate the motivations behind the over-achievement of Shanxi. However, at this stage, it is assumed that the fear of failure to

achieve performance targets and the willingness to impress higher authorities promoted transition rates that exceeded the planned targets.

Unfortunately, the rapid and large-scale transition cleaned the winter air, but failed to secure sufficient heating for the residents of Shanxi; they had to endure the cold winters. These adverse consequences impacted the national energy transition plan. The central government had to urgently adjust clean heating transition measures to address inadequate heating supply and reverse its ambitious plans on coal bans and promoting gas plants. This implies that recentralization may have been able to provide proper incentives to prioritize the environmental issues as much as economic growth, but it could not control the autonomy of how local governments and how it achieved the central targets. As a result, recentralization was not as effective as theoretically anticipated and undermined energy transition efforts.

In China, the central government announced the policies and the local governments implemented them. If this resulted in adverse results, emergency documents were issued to correct the original plans. For the clean heating transition, an identical cycle was repeated. However, the insufficient heating supply caused by the gas shortage was far from sufficient to be resolved by urgent documents with a message of easing the coal ban. To speed up the conversion and encourage local residents to participate in transition tasks, the coal stoves were removed before the clean heating devices were properly installed. Therefore, even if coal re-combustion was allowed, heating could not be supplied. Since the recentralization of environmental governance could not control the autonomy of local governments, the cadre responsibility and evaluation system should prepare new incentives, punishment or revision of the cadre evaluation indicators to prevent the implementation process from being distorted.

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