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Original Research

The Unintended Impact of Environmental Regulation on China's Hog Sector

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Abstract

Environmental regulations in China's hog industry aim to adjust industrial layout and reduce pollution. However, these regulations have had an unexpected impact, resulting in varying degrees of hog production decline across regions. This study, is exploring how environmental regulations affect lost hog production in multiple ways through increased supervision and penalties, differentiation of enforcement agents, and indiscriminate closure of farms with non-livestock production areas. Subsequently, employing the Difference-in-Difference approach, we empirically test the effects of these regulations on the hog industry using a unique panel of national county-level hog production data. Our results demonstrate an unexpected decline in hog production, primarily observed in the two key production areas. This suggests that China's hog industry has not experienced a dominant industrial layout adjustment in response to environmental regulation. These findings underscore the need for more precise regulatory standards and stronger enforcement bodies in China's future reforms, with an emphasis on central rather than local-based regulation. This approach is critical for maintaining stable production while reducing pollution.

Keywords: campaign-style enforcement, environmental regulations, hog breeding, agricultural pollution, China

Introduction

In recent years, the issue of water pollution caused by hog production has emerged as a major environmental concern in China. According to the statistics, in 2017, the livestock and poultry breeding industry discharged 10,005,300 tons of chemical oxygen demand and 110,900 tons of ammonia nitrogen, accounting for 93.76% and 51.30% of agricultural source water pollution [1]. The industrialization of livestock breeding has posed significant challenges in tackling environmental pollution in China [2], and non-point source pollution in agriculture has remained at alarming levels [3]. In response to this, the State Council introduced the Regulations on Water Pollution of Livestock and Poultry Sectors (henceforth referred to as the Regulation) in January 2014, which is considered to be the most rigorous water regulation for hog sectors in China to date. The Regulation defines non-livestock production regions (NLPRs) [4] and allocates hog

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production space to mitigate pollution problems in major water areas[1].

Since 2014, key provinces and regions in China have launched enforcement campaigns to control pollution caused by hog farming. Given the large number of small-scale producers and farmers that dominate the hog production market in China, monitoring these decentralized farms presents significant challenges. In response, local governments have adopted more radical campaign-style place-based approaches, such as the establishment of NLPRs with broader scopes. However, these local implementers may have forgotten that the policy seeks to reallocate hog production, reduce pollution, and maintain market supply. Data from the National Bureau of Statistics reveals a significant 25.4% decrease in pig stocks and a 28.9% reduction in sow stocks from 2013 to 2017, implying broader impacts of local government regulations beyond policy enforcement. How do local government implementers balance the reallocation of hog production, pollution reduction, and market supply maintenance, and what are the broader implications of their actions?

Existing studies have shown that environmental regulations can negatively impact hog production, leading to a reduction in the number of hogs slaughtered, live hog inventory, and pork production by 8.3%, 10.3%, and 11.2%, respectively [5]. Zeng et al. (2022) [6] used a spatial econometric approach to show that these regulations significantly impact the hog industry in highly regulated areas. These studies evaluating hog-relocation policies and regulations have consistently shown that such regulations lead to reduced animal numbers rather than the relocation of production capacity [5, 6]. Despite these efforts, there is a notable gap in the comprehensive analysis of how campaign-style enforcement strategies have impacted the creation of wider NLPRs at the local level and the specific mechanisms through which these measures have resulted in reduced hog production in China.

To bridge the gap, we focus on whether and how the Regulation may reduce hog production through the lens of campaign-style enforcement. We assert that the Regulation could have a negative policy effect on hog production, shedding light on fundamental issues within the environmental protection system. In terms of empirical evidence, we collected year-end hog inventory data for 1,192 counties from 2006 to 2017 and estimated the policy effects of the Regulation on the hog industry using a Difference-in-Differences (DID) model. Our findings underscore the unintended consequence of campaign-style enforcement, leading to a significant reduction in hog production. We attribute this outcome to inherent flaws within the environmental protection system, which subsequently results in variations in enforcement practices at the local level. Through further analysis, we find that perhaps some important regions are subject to more severe environmental regulation.

Then, our article fills in this important gap on how campaign-style regulation affects hog production. Firstly, while campaign-style enforcement resolves the problem of local governments delaying the implementation of environmental policies, it fails to prevent them from resorting to drastic measures such as reducing hog production. Secondly, discrepancies in the ultimate policy objectives and implementation strategies among various stakeholders often result in farm closures as a means to achieve the overall pollution reduction goal. Lastly, it is essential to acknowledge that livestock farming pollution control is just one aspect of China's broader efforts to combat environmental pollution like industrial pollution control, farms in NLPRs have been subjected to indiscriminate shutdowns.

Our article delves deep into the impact of campaign-style regulation on hog production, offering a fresh perspective on an understudied subject. First and foremost, this paper contributes to understanding how campaign-style regulation impacts the hog production industry [5, 6]. We serve as an illuminating exploration of the intricate ways in which campaign-style regulation exerts influence on the hog production industry, shedding light on the often-overlooked complexities, consequences, and implications of this regulatory approach. Second, our paper resonates with other studies [7] that emphasize the potential long-term effects of campaign-style enforcement on environmental governance. Our theoretical contribution, however, focuses on discussing the different impact mechanisms of this long-term impact in the agricultural sector. By delving into previously unexplored dimensions, our research uncovers unique insights that contribute to the broader knowledge base, enabling more persuasive and evidence-based scientific research on environmental regulation for developing countries, typified by China, thereby adding substantial scientific reference value to the development of environmental regulation in these countries. We also have attempted to provide empirical marginal contributions through a more detailed empirical analysis.

The remainder of this paper is organized as follows. Section 2 is material and method which describes the literature review of the campaign-style enforcement, and the mechanism of the campaign-style regulation and presents the empirical framework of this study. Section 3 presents the data source and data construction, and reports the regression results. Section 4 states the conclusions of the study.

[1] The NLPRs include drinking water source protection areas, scenic spots, core areas and buffer zones of nature reserves, the main area of human activity (such as urban residential areas, educational and scientific research areas, and other densely populated areas), and other prohibited breeding areas stipulated by laws and regulations.

Material and Methods

Campaign-Style Enforcement Literature Review

As reported in the literature, campaign-style enforcement involves the deployment of extraordinary resources at a specific time to achieve clear policy objectives and targets for regulation, with the aim of bridging the gap between regulation and compliance enforcement [7, 8]. In China's political process, campaign-style governance is frequently employed and is particularly evident in agricultural pollution control. The Regulations exhibit the characteristics of "campaign-style enforcement", which refer to any special action to deal with major and prominent problems in a short time.

Campaign-style governance is not unique to China but is employed in many countries to achieve urgent policy goals, such as road safety [9, 10], anticorruption [11, 12], and environmental regulation [7, 13]. However, some scholars have argued that this type of governance can have negative impacts [14, 15]. In the context of campaign-style governance, the state may announce massive indiscriminate penalties for polluters, plant closures, and stop-production action plans to solve major environmental problems quickly and in the short term, resulting in downstream effects and border effects based on the accumulation of dirty firms in specific counties, which has led to the transfer of pollution and superficiality of governance results [3, 13, 15-19].

The previous literature have offered different insight into campaign-style environmental enforcement in China, but few of have disscused the working mechanism of the campaign-style environmental enforcement. Liu et al. [7] developed a theoretical model on campaign enforcement that addresses the decoupling of regulatory compliance through two recoupling mechanisms, resource mobilization and power redistribution, a two-way mechanism that explains the effectiveness of campaign enforcement on the implementation of energy efficiency and emission reduction policies in China. Jia & Chen [8] summarize the root causes of poor environmental performance in terms of local incentive structures, internal bureaucratic dynamics, and social pressures and examine how a new environmental campaign-style enforcement mechanism, the central environmental protection work inspection, can improve environmental performance in the form of external incentives.

Unlike industry, the agricultural sector in China has yet to witness significant advancements in environmental protection. Consequently, the hog industry has experienced an unprecedented consolidation process driven by livestock farming pollution control measures, which include the drastic reduction of farming space. To gain a deeper understanding of how the Regulation impacts hog production capacity, it is crucial to analyze the underlying enforcement mechanism behind this campaign-style regulation.

Remarkably, there is currently a lack of research articles examining the impact and mechanism of environmental regulation on China's livestock industry, even at a theoretical level. Therefore, our study aims to address this knowledge gap by constructing the most comprehensive county-level hog production dataset available. By subjecting this dataset to critical analysis and empirical testing, we can shed light on the implementation and validity of the Regulation. Through these research endeavors, our study seeks to complement the existing literature on environmental regulation in the agricultural sector, specifically in relation to campaign-based enforcement. By providing valuable insights and empirical evidence, we aim to contribute to a deeper understanding of the effects of environmental regulations on the livestock industry in China.

Nature of the Regulation

In this section, we attempt to examine how campaign enforcement can produce detrimental changes in the hog industry in three ways: the disconnect between central and local levels, multiple enforcement objectives, and the emphasis on accountability over incentives [7, 20], to help understand the root causes of the failure of campaign enforcement to produce positive environmental performance in the agricultural sector. These mechanisms are as follows:

First and most importantly, campaign enforcement helps mobilize administrative resources to address local enforcers' delays in enforcing or failing to enforce regulations, but it cannot avoid blunt-force enforcement. Campaign enforcement helps to bridge the gap between environmental implementation performance and policy goals by mobilizing administrative resources [7], and change bureaucratic inaction by elevating the priority of centrally important matters and the status of local Environmental Protection Bureau (EPB), promoting the efficiency of environmental protection at local levels [21]. It also temporarily replaces the working mechanism of direct leadership and supervision by higher-level campaign initiators to break down information asymmetries and strengthen the balance between conflicting local interests [22].

Despite the severe water pollution caused by agricultural production after the 11^{th}-12^{th} Five-Year Plan, China has persisted in adopting strict environmental regulations, and the intensity of these regulations is increasing. Typically, this is followed by a massive campaign to achieve the country's environmental goals, demonstrating the central government's commitment to environmental management [23]. China's target-based approach to implementation has encouraged local officials to strictly enforce environmental mandates [24]. While targets make it easier for higher-level organizations to drive results-oriented execution, they are imposed at every level, and excessive or clumsy execution is unavoidable [25]. Obviously, the local government model of environmental governance is often crisis-driven, with short-term ecological conservation services effectively addressing individual problems but struggling to promote sustainable.

After the central government released the regulation, the Department of Ecology and Environment requires EPB to submit a comprehensive report on the local livestock and poultry farming situation, which should include essential information about the farm such as the farmer's basic information, farm location, farming scale, site conditions, sewage equipment, and any other relevant details. A list of local businesses and a summary of local hog production was used by EPB to close all farms in the prohibited areas without discrimination, as well as all backyard farming sites. For substandard large-scale farms outside the exclusion zone, they will receive a warning and be required to build or upgrade their sewage equipment. If these farms fail to take further measures, their farms will be shut down. Backyard farming sites that are not up to scale are also required to shut down without room for negotiation. As a result, livestock production was banned in some regions. By 2017, 90,000 non-livestock production regions had been established, covering a land area of 0.82 million km^2, and 0.26 million hog farms had been shut down [4].

The second point is that having multiple enforcement subjects may lead to deviations from campaign-style governance outcomes and policy goals. In China, campaign-style governance goals usually involve multiple subjects with conflicting goals. For example, in the case of preventing pollution from livestock and poultry breeding, multiple departments of the State Council, the Ministry of Agriculture and Rural Affairs[2], and the Ministry of Ecology and Environment are involved. The State Council primarily plays a coordinating role, while the Ministry of Agriculture and Rural Affairs and the Ministry of Ecology and Environment work together to complete pollution control. Since the Ministry of Ecology and Environment bears the primary responsibility for preventing and controlling environmental pollution, it has weakened the voice of the agricultural sector and strengthened the absolute position of the environmental sector in this operation. Unlike polluting factories [26], farms provide minimal economic benefits, and localities have no vested interest to delay policy goals set by the central government. However, the EPB has displayed unprecedented decisiveness in closing down non-compliant livestock farms and backyard farms.

Until 2018, agricultural bureaus at all levels, including the Ministry of Agriculture and Rural Affairs, had departments responsible for ecological monitoring. These departments were primarily responsible for setting environmental regulation standards and regulating the quality of the agro-ecological environment. In China, the Ministry of Agriculture and Rural Affairs is responsible for a wide range of tasks such as directing the production of agricultural products like grain, overseeing and managing the quality and safety of agricultural products, monitoring and directing the environmental quality of agricultural production areas, and promoting clean production.

There are multiple regulatory bodies involved in the field of agricultural pollution prevention and control, which can lead to differences in campaign enforcement goals and policies. These differences in goals are referred to as "target differences." The agricultural sector has set more stringent policy goals than the State Council and the ecological environment sector. When the regional agricultural departments were the primary enforcers, the pollution data provided by EPBs prompted them to choose stricter enforcement standards and more decisive enforcement, even though they also had the primary responsibility for agricultural production and supply.

In 2019, the Ministry of Agriculture and Rural Development, along with the Ministry of Ecology and Environment, issued a document that stipulated the scientific delineation of no-breeding zones in compliance with the law, and the prompt abolition of no-breeding zones that exceed the legal limits or are superfluous. By 2021, a total of 86,000 no-breeding zones have been legally designated, covering an area of 1.212 million square kilometers. Furthermore, there have been adjustments to reduce the number of no-breeding zones designated without the basis of laws and regulations, with 14,100 such areas covering an area of 129,000 square kilometers being removed.

Last but not least, the adoption of campaign-style enforcement has increased the emphasis on environmental accountability, thereby compelling local authorities to enforce compliance. The root cause of the current poor environmental performance may be that the existing incentive programs are inadequate in motivating localities to carry out environmental enforcement in a timely manner [20]. To accurately assess local environmental management effectiveness, the central government has established air quality monitoring points and constructed an automatic surface water environmental monitoring network, providing data support for local environmental assessments. This system can decrease the likelihood of pollution data falsification, enhance regulatory efficiency, and have a positive impact on pollution reduction. However, it does not fundamentally alter the environmental management system, and local environmental protection departments are still responsible for enforcing environmental regulations.

The incentive structure needs to be significantly changed by the central government to prioritize environmental protection, given the inherent conflict between local economic development and environmental protection [8].

2 China's agricultural institutions are, from top to bottom, the Ministry of Agriculture and Rural Affairs (national level), the Department of Agriculture and Rural Affairs (provincial level), and the Agriculture and Rural Affairs Bureau (city and county level).

In 2007, Dongguan City in Guangdong Province completed the cleanup of pollution caused by the farming industry. More than 15,000 hog farms were closed down, and over 2 million hogs were cleaned up, while 7,702,800 square meters of farm support facilities were demolished. The cleanup compensation amounted to 450 million yuan. The national target set for Dongguan City was to control the total COD (chemical oxygen demand) within 100,000 tons by 2010. It is important to note that every 750,000 live hogs produce 17,000 tons of COD. The city had identified 1,252 key polluting enterprises in six industries, including electroplating, bleaching and dyeing, paper making, tanning, washing, and printing. These industries accounted for 8.5% of the city's total industrial output value in 2005, but their wastewater emissions accounted for 78% of the city's total industrial wastewater emissions. It is evident that the city's Environmental Protection Bureau was more determined to combat agricultural pollution than industrial pollution.

In summary, as explained in the mechanisms described above, the main theoretical hypothesis of this paper is that campaign-style enforcement, such as the Regulation, has led to the implementation of strict local enforcement measures that have had a long-term impact on reducing hog production.

Results and Discussion

Empirical Framework

The focus of our study is to analyze the unintended impact of campaign-style enforcement, specifically the Regulations, on county-level hog production. We hypothesize that hog production will decrease more significantly in regions with stricter targeted regulations than in regions with relatively lenient enforcement, while hog production in areas with more generous environmental regulations should either be unaffected or increase in production in that area. Based on the content of the Regulation, restricted development areas are required to complete enforcement by the end of 2017. Since the policy explicitly requires the content and timeline of enforcement for the treatment group, which provides very good exogenous conditions for us to construct a quasi-natural experiment, we designate the restricted development areas as the treatment group and the key development area as the control group (refer to Fig. 1). To identify the causal impact of the Regulations on different regions, we employ a difference-in-differences (DID) approach. Our basic DID specification is presented as follows:

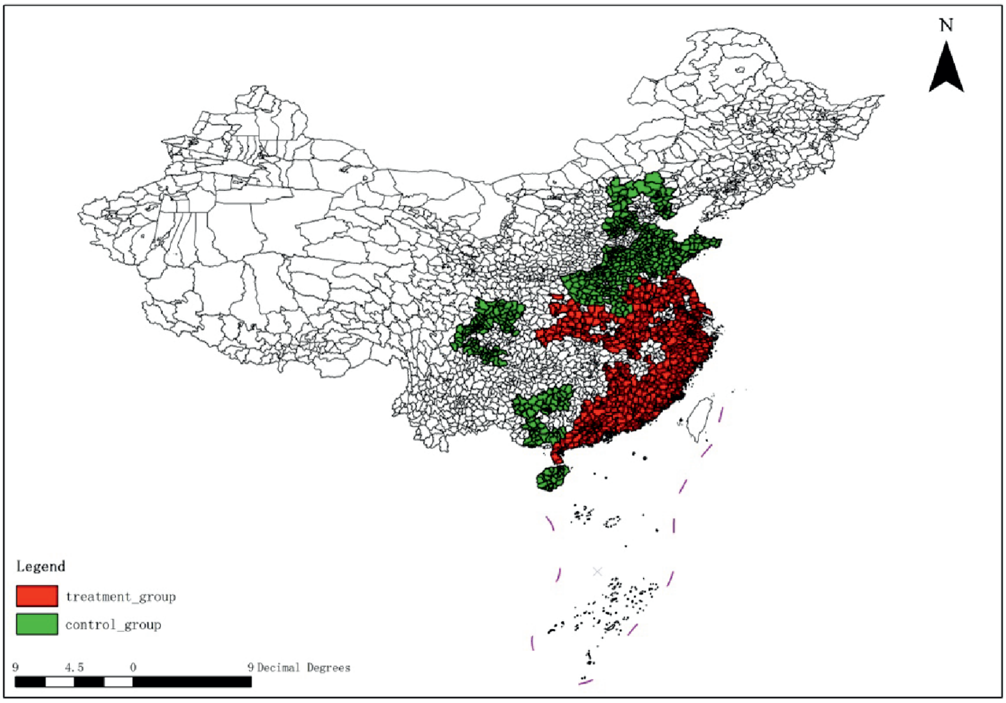

Fig. 1. Treatment group and control group area illustration.
Note: The legend shows that the red and green parts represent the study areas, with green being the control group and red being the treatment group. Areas with no fill color indicate counties with missing data. The treatment group consists of Guangdong, Fujian, Jiangxi, Zhejiang, Jiangsu, Anhui, and Hubei, while the control group includes Shandong, Hebei, Henan, Hunan, Sichuan, Guangxi Zhuang Autonomous Region, and Hainan. Due to a large annual data gap in Hunan Province, it was excluded from the research scope of the control group. The provinces of Guangxi, Sichuan, and Jiangxi experienced the most severe data loss. For further information on hog inventory and slaughter in restricted and key development zones from 2014 to 2015, please see Appendix Table 1.

$$LnInven_{ct} = \beta_0 + \beta_1 rt_{ct} + \beta_2 \text{Control}_{ct} + \alpha_c + \gamma_t + \varepsilon_{ct} \quad (1)$$

where $LnInven_{ct}$ is the log-transformed outcome variable (either hog inventory or slaughter) of county c in year t. $rt_{ct} = treatmen_c \cdot post_{ct}$, where $treatment_c = 1$ if county c in the treatment group area, and otherwise 0. $post_{ct}$ is a post-treatment indicator, taking a value of 1 if $t \geq 2014$, where 2014 is the year of the Regulation implementation year, and 0 otherwise. The key parameter of interest, β_1, measures the causal effects of the Regulation of hog inventory or production. $Control_{ct}$ is an additional control to further address the fact that socio-economic conditions could be hypothetically correlated with the implementation time of the Regulation and the hog industry. α_c are county fixed effects capturing time-invariant unobservable that could confound the estimated effects. γ_t is the time fixed effects capturing time trends common across all counties.

The treatment and control groups were selected based on the principles outline in the Hog Production Development Plan (2016-2020) released by the Chinese Ministry of Agriculture in 2016, which divided the country into four areas: restricted development area, key development area, moderate development area, and potential development area. Hog production in the restricted and key development areas accounts for about 70% of the total hog slaughter in the country. The policy mandating the delineation of NLPRs by the end of 2017 in the restricted development area has not been implemented in the key development area, leading to an anticipated annual 1% increase in hog production in the latter due to the closure of numerous farms in the restricted development area. Our hypothesis is that the treatment group will be subject to environmental regulations earlier and with higher intensity than the control group, leading to a decrease in hog production. In contrast, the hog industrial in the control group is expected to have further development to make up for the loss of hogs in the treatment group due to the NLPRs.

Data Source and Data Description

Data Source

This part of the empirical county data is mainly obtained from municipal statistical yearbooks, which the authors collated by locating the publicly available statistical yearbooks of each municipal statistical bureau. For municipalities that do not have publicly available statistical yearbooks, they were obtained by applying to the statistical bureaus to disclose economic data relevant to this study. In this study, we collected data on county-level hog inventory and slaughter, as well as socioeconomic data and river conditions. The hog inventory data were collected for 1,192 counties[3] in 13 provinces from 2006 to 2017, covering two phases of environmental regulation (see Table 1). Hunan province was excluded from the dataset due to missing data (see Fig. 1). The hog stock in these 1192 counties represented around 50% of the national total in 2014. Below, we describe these three datasets in more detail.

Data Description

Hog production. In this study, we followed the approach of previous studies [5, 6] in using the number of stocked heads as an indicator of hog production. Specifically, we used the natural logarithm of year-end hog stock in each county as the outcome measure. This variable was chosen because it is commonly used by provinces as an indicator to measure the impact of environmental regulations on hog production. The data used in this study were obtained from various sources, including publicly available yearbook data from data statistics departments and data obtained through requests to local data statistics departments. Fig. 2 presents hog production for the treatment and control groups from 2006 to 2017. Our results show a significant reduction in hog inventory in the policy year (2014), with a reduction in production occurring earlier in the control group than in the treatment group. To combine the other variables in the study for each county included in the dataset, a unique code was generated.

Socio-economic data. This study includes regional socioeconomic characteristics that may affect the estimation but cannot be captured by county and year-fixed effects. This socioeconomic dataset includes information on prefecture-level GDP, the total population at the end of the year, per capita gross domestic product, disposable income of rural residents, and total grain output. The following are the reasons for including these variables: (1) more developed regions are more committed to environmental governance, and the intensity of environmental regulation is higher than that of relatively backward regions. (2) total population at year-end reflects the local consumption capacity to some extent. (3) Per capita GDP (*GDP_pc*) further explains the impact of the economy and consumer market on hog production. (4) The hog industry is a vital agriculture pillar closely related to farmers' income. (5) Some studies believe that the main grain-producing area has gradually become the main hog-producing area. To reduce the heteroskedasticity in the panel data, we applied logarithms to all control variables. To ensure that there is no high correlation between the explanatory variables that might bias the model estimation results, we conducted a covariance analysis on the explanatory

[3] The current administrative division in China is central government - province (municipality directly under the central government) - city - county (municipal district) - town - township.

Table 1. Summary statistics.

Name of variable	Observation	Mean	Standard deviation	Min	Max
GDP	15,496	2606.467	2756.583	119.61	24221.98
GDP_pc	15,496	42708.97	29404.88	2908.258	191942
Total population	15,496	566.5444	274.665	82.21	1478.1
Income	15,415	10379.16	5835.864	863.1	34279
Grain yield	14,959	231.8876	186.8311	.0005	901.9
Hog inventory (10,000)	15,237	21.75518	21.70318	0	262.61
Hog slaughter (10,000)	14,626	32.32853	32.04811	0	270.77

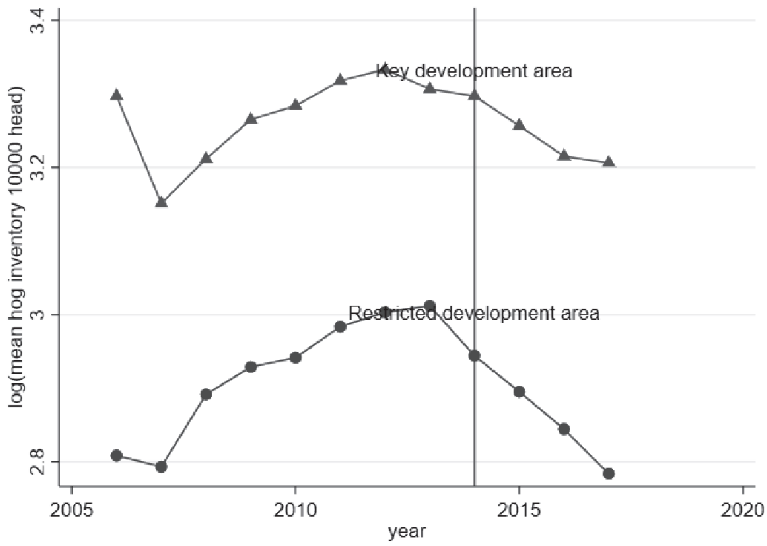

Fig. 2. The production of hogs in the treatment and control groups.

variables. The results showed that the variance inflation factor (VIF) value of each explanatory variable is less than 10, indicating no evidence of multicollinearity between the explanatory variables.

Water resource. Our research areas include

– the Pearl River water network area,
– the Yangtze River Delta water network area,
– the middle reaches of the Yangtze River water network area,
– the lower reaches of the Huaihe River water network area, and
– the Danjiang Estuary Reservoir area.

The counties in which these watersheds are located all share the following characteristics: population concentrations, abundant resources, convenient transportation, and critical national bases for food production, energy and minerals, and manufacturing. Based on the essential objective of the regulation is to control water pollution, our study will take the river areas above class III as a vital part of the regional difference analysis and further explore the environmental regulatory differences between the critical watersheds and other areas.

The Baseline Results

The results of the base DID model, as shown in Equation (1), are presented in Table 2. Columns 2-3 show the base DID results for the implementation of the different regions. The implementation of environmental regulation had a significantly negative impact on hog inventory at the 1% level. After the implementation of the policy, the hog inventory capacity in restricted development areas decreased by 9% compared to that in key development areas.

Table 2, Column (1) shows the OLS regression, while columns (2) and (3) show the DID with double fixed effects. In response to the insignificant parallel trend in the treatment and control groups observed in Fig. 2, we conducted a robustness analysis by not only verifying that our study meets the assumptions used in the DID model through the event study method but also adding a time trend term in the regression of column (3) to strengthen the stability of the parallel trend assumption [27]. The results in columns (2) and (3) show that the effect of environmental regulation on hog production is significantly negative at the 1% statistical level.

Table 2. Baseline results of DID estimates.

	Log (inventory)			Log (slaughter)	
Dependent Var.	(1)	(2)	(3)	(4)	(5)
rt	-0.396***	-0.0931***	-0.0933***	-0.0775***	-0.0664***
	(0.0260)	(0.0225)	(0.0235)	(0.0247)	(0.0249)
Control Var.	—	—	Yes	—	Yes
Year FE	—	Yes	Yes	Yes	Yes
County FE	—	Yes	Yes	Yes	Yes
Time trend	—	—	Yes	—	Yes
observations	14,068	14,068	13,547	13,469	12,959
R-squared	0.016	0.955	0.957	0.955	0.957

Note: The outcome variables in columns 1-3 is the hog inventory, and the outcome variables in columns 4-5 are the hog slaughter. Column 1 shows the OLS regression results; Columns 2-5 are the baseline results of the DID estimates. The log of hog slaughter is used to replace the outcome variable as a robustness analysis. Robust standard errors are shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The average treatment effect of the model indicates that there was a reduction in hog stock in both the restricted development area and the key development area during the implementation of environmental regulation, which contradicts the policy's objective of stable and increased production. The regression results indicate that after the implementation of the environmental regulation policy, the hog production capacity in the restricted development area decreased by 9% more than that in the key development area, suggesting that the implementation of the environmental regulation policy in the hog industry had a negative effect. The restricted development area (treatment group) adopted stricter and faster environmental regulation than the key development area (control group). In contrast to our policy expectations, hog production capacity in the crucial development zones has not met the expected increase, and their capacity has been somewhat impacted by environmental regulations.

During our research in Guangdong Province, our team found that some regions have different standards for the delineation of NLPRs, and some have exceeded the legal limits for NLPRs. The adoption of "one-size-fits-all" practices, such as indiscriminate shutdown and strict emission standards for pig breeding in NLPRs, has seriously compressed the development space of the hog industry.

We believe there is uncertainty about the conditions required to implement a place-based policy successfully. Immediately after the implementation of the regulations in 2014, some provinces strengthened the prevention and control of livestock and poultry farming pollution, particularly in southern provinces such as Zhejiang, Fujian, Hubei, and Guangdong. These provinces accelerated the delineation of NLPRs and made significant efforts to regulate backyard farmers. Because provincial ecological departments have not been trained in centralized policy development and have not been provided with detailed standards for implementing regulations, top policymakers in each province tend to develop policy implementation plans that are more stringent than national standards, taking into account the agricultural production situation, socioeconomic conditions, and preferences within their jurisdictions. This is called "local adaptation" in China, which means that each province sets different policy standards within the national policy framework according to the actual situation in each province. That is why there is a significant difference between the two groups.

Robustness Checks

Fig. 3 presents the results of the first scenario as a robustness check. The validity of the DID specification relies on the assumption that both the treatment and control groups follow a parallel trend. The event study method can test whether the two groups maintain a parallel trend before the implementation of the policy year. Fig. 3 plots the policy effect coefficient under a 95% confidence interval. Before the implementation of the policy, the coefficient of the policy effect is not significant and fluctuates between zero. After 2014, the policy effect was significantly negative, and the policy effect also maintained a significant negative trend from 2014 to 2017.

As a second step to test the robustness of our results, we replaced the outcome variable by using the number of hogs slaughtered at the end of the year to effectively analyze the difference in the implementation of environmental regulations. As shown in columns 4-5 of Table 2, the environmental regulation variables remain significantly negative. Moreover, there are differences in the intensity of hog production across different regions, which is consistent with the main findings of this study.

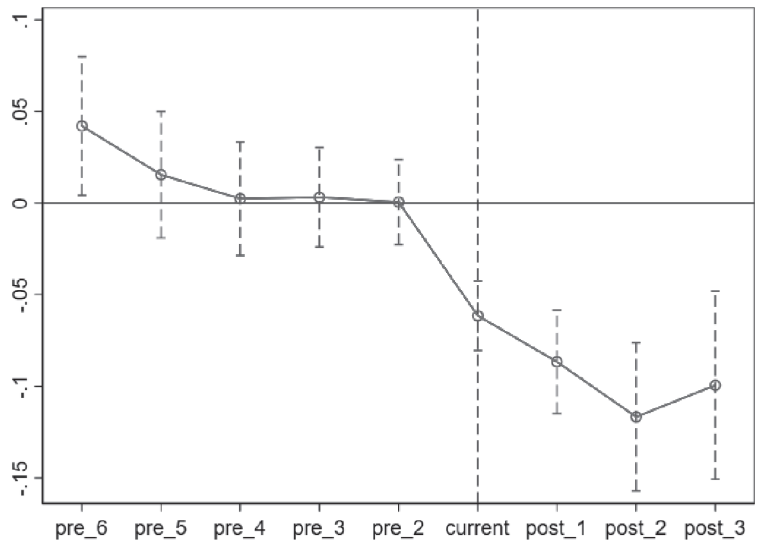

Fig. 3. Event study evidence from the assumption of a parallel trend.
Note: Analyze the processing group from 2008 to 2017 and select the year before the policy pre_1 as the benchmark. The horizontal axis represents the years, with the current year representing the policy year (2014). The year 2013 was omitted in the regression process. The regression results are presented for the years 2008-2012 (pre_6, pre_5, pre_4, pre_3, and pre_2) and the years 2015-2017 after the policy year (post_1, post_2, and post_3). The vertical axis shows the regression coefficients. If the coefficients fluctuate around zero, it means that the year is not significantly affected by the regulation.

Third, to examine the robustness of our results, we conducted a placebo test to check for any potential influence of omitted variables. Specifically, we randomly assigned the adoption of environmental regulations to counties to see if the estimated coefficients would still hold. Fig. 4 shows the distribution of the estimated coefficients of 500 "pseudo policy dummy variables" and their corresponding P values. The kernel density distribution of the estimated coefficients is shown as a curve, the blue dot represents the p-value of the estimated coefficient, and the vertical dotted line represents the real estimated value of β_1. As seen in the figure, most of the estimated coefficients are concentrated near the zero point. Moreover, the p-value of most estimation values is greater than 0.1, indicating that the baseline estimation results mentioned above are unlikely to be affected by other policies or random factors. Therefore, the conclusion on the negative impact of livestock and poultry pollution regulation on hog production in the context of campaign enforcement is stable.

Finally, in our base model, we clustered the standard errors at the county level. As a robustness check, we re-clustered the standard errors at the province level. Given the significant differences between counties

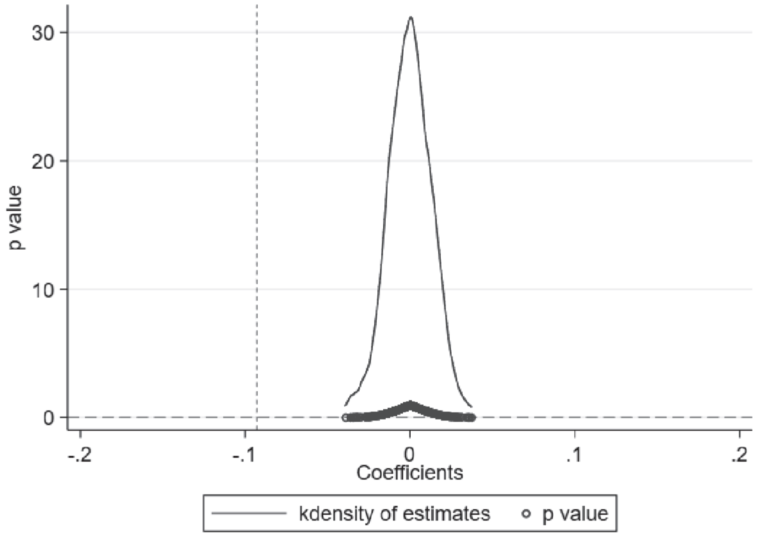

Fig. 4. Placebo test .

and provinces, we used the synthetic control group constructed using the synthetic control method based on the provincial data as a counterfactual reference for the treatment group [28]. The original experimental design of the synthetic control method is for only one treatment individual. The most typical study is that Abadie et al. (2010) [29] used the synthetic control method to study the effect of the 1988 Proposition 99 in California, USA. However, since our research unit is the county, to better integrate the synthetic control method with our research, we used the synthetic control method (with multiple treated units) to search for the synthetic control group using provincial data. The synthetic control method can select the optimal weight of the linear combination according to the data, avoiding subjectivity in control group selection. In Fig. 5, the synthetic control group maintains a consistent change trend with the treatment group before the policy treatment year and serves as a good reference group for the treatment group. Fig. 6 plots the policy treatment effect. After the policy treatment year, the control group was subject to significantly more stringent policies, and the policy effect was still negative, which is consistent with the main conclusions of this study.

Heterogeneity Analysis

Consistent with previous research, we have found that campaign-style enforcement is crucial for promoting local officials' environmental governance, and regional differences exist in the development and implementation of environmental regulations [26, 30]. These differences are not only present at the provincial level but also among different municipalities

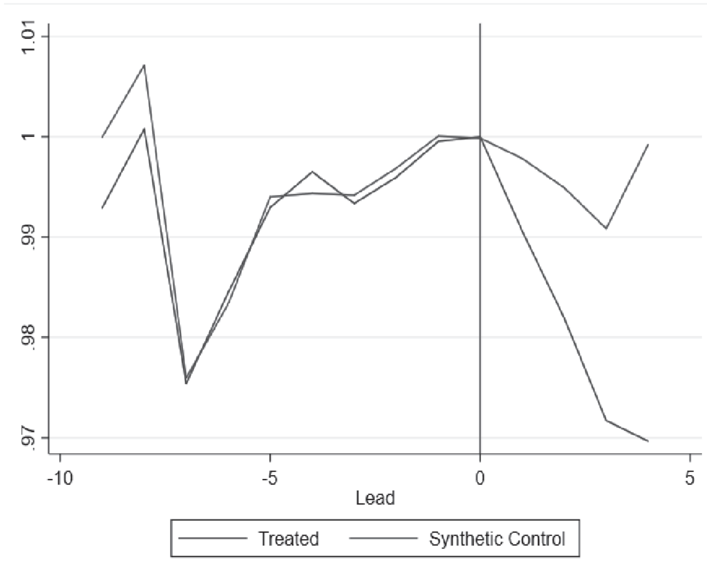

Fig. 5. Synthesis effect.

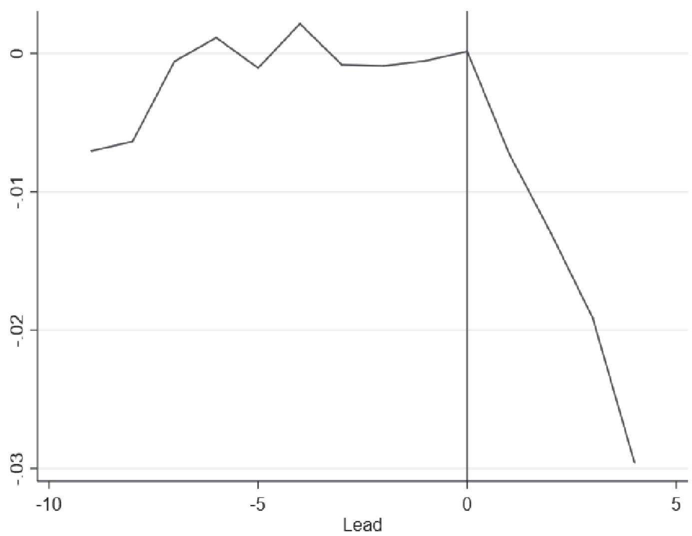

Fig. 6. Treatment effect.

within the same province. Our study revealed that differences in the implementation of environmental regulations existed only between the treatment and control groups and within-province differences in the implementation of environmental regulations. To examine within-province differences in implementation and to gain further insights into environmental enforcement in more typical geographic areas, we further included the:

– the counties through which important rivers flow,
– the counties related to the southern water network,
– key counties for hog production,
– major urban areas,
– border counties of neighboring provinces as the third level of different areas.

The results reveal that the β_1 coefficients are consistently significant, but none of the DDD coefficients demonstrate significance. Of particular interest to

Table 3. The results of the DDD estimate.

	(1)	(2)	(3)	(4)	(5)
rt	-0.110**	-0.0838***	-0.0738***	-0.0750***	-0.115***
	(0.0477)	(0.0277)	(0.0227)	(0.0261)	(0.0283)
River	0.0141				
	(0.0545)				
river*treatment	-0.0443				
	(0.0335)				
Water		-0.0677			
		(0.0571)			
Water*treatment		0.0583			
		(0.0422)			
Primary			-0.0394		
			(0.136)		
primary*treatment			-0.0581		
			(0.119)		
Urban				-0.0501	
				(0.0532)	
urban*treatment				-0.0602**	
				(0.0290)	
Border					0.0792
					(0.0489)
border*treatment					0.0175
					(0.0253)
Constant	2.663**	2.729**	3.201***	2.878***	2.835**
	(1.119)	(1.144)	(1.212)	(1.108)	(1.102)
Year FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	13,547	13,547	13,547	13,547	13,547
R-squared	0.957	0.957	0.957	0.957	0.957

Note: River is the interaction term of the county and rt related to the third level river system and above, expressed as . Water is the interaction item between counties and rt related to essential water systems in southeast provinces., expressed as . Primary is the area of key hog breeding counties, expressed as . Urban is Urban is the interaction item between counties and rt that belong to the main center of the city, expressed as . Border is the interaction item between counties bordering neighboring provinces on the border of those provinces and rt, expressed as . Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

us, regarding the 4.3 section on water resources, are the coefficients for River and Water triple interaction terms, which were not significant. The insignificance of the triple interaction term coefficients for central hog-producing counties may be because these large-scale production counties can receive state subsidies for agricultural production, and thus, no strict law enforcement is applied to them. Furthermore, the coefficients of the triple interaction term for major urban areas are all insignificant. However, their coefficients' direction aligns with our prediction, where the interaction term for urban areas and the policy time variable is significant, indicating that urban areas are subject to stricter environmental regulations than rural areas. The coefficient on the triple interaction term for border counties is also insignificant, but the direction of its coefficient supports our further investigation into why border counties are more likely to develop agriculture.

Discussion

Studies have suggested that campaign-style enforcement is effective in achieving short-term positive policy outcomes due to the concentration of resources and strong political incentives [7, 8, 31]. However, it has also been argued that campaign-based enforcement is temporary and fails to address the underlying problems of environmental pollution, leading to unsustainable effects [21, 26]. Additionally, some experts argue that campaign-style enforcement may undermine long-term environmental performance as it often involves uncertain enforcement and contradicts conventional practices [30]. However, there have been few studies on the application of environmental campaign-based enforcement in the field of livestock and poultry pollution, and even fewer analyses of the mechanisms of campaign-based enforcement in this context.

Through a mechanistic analysis, we suggest that the reduction in hog production as a result of environmental regulations may be due to local bureaucrats' tendency to exceed their targets when implementing these regulations to meet higher authorities' reduction targets. China's environmental governance system employs a different restraint mechanism with stricter target assessment rules than that of developed countries. Binding environmental objectives are passed down from the central to the county level, and each administrative level has the autonomy to allocate goals among departments, lower levels of government, and enterprises. This institutional background allows China to achieve more intuitive results by adopting campaign-style enforcement to govern the environment, despite its unintended consequences.

However, why does China continue to use campaign-style governance for environmental issues, despite its unintended consequences? We argue that this preference partly results from the regulatory system's characteristics, under which the central government holds considerable legislative power and retains absolute authority over environmental planning, while the local government has complete law enforcement and decision-making power. This model of top-level design and local implementation often leads to the central government's insufficient resources to supervise the contamination situation, leads to poor enforcement of environmental regulations or unexpected results.

The current target-based environmental management approach in China provides greater flexibility in target allocation than commonly believed. Local bureaucrats often adjust targets according to regional conditions when targets are passed down to the administrative level. In addition, local governments involve multiple departments in the enforcement process, such as the agricultural sector and the ecological protection department, resulting in unintended consequences due to differences in the setting of the main objectives in the implementation of this policy.

In the context of increasing pressure from environmental regulations, the outbreak of African swine fever in 2018 had a significant impact on the hog supply market. Additionally, the price of live hogs has been volatile in recent years. On December 6, 2019, the Ministry of Agriculture and Rural Affairs announced the Three-Year Action Plan for Accelerating the Recovery and Development of Pig Production, which is a new round of campaign-style law enforcement against the pig industry after the campaign environmental law enforcement. We argue that when the unintended consequences of environmental regulation are triggered, it will trigger a new round of movement, like the Three-year Action. Like a cycle, won't the next round trigger a new round of environmental tightening?

Conclusions

In this paper, we conduct an empirical evaluation of a campaign-style regulation that requires local governments to complete water pollution control tasks within a specific period. Surprisingly, we find that instead of reducing pollution discharges to improve water quality, local governments' pollution control approach is to reduce hog production, as directed by the policy. We use China's 2014 livestock environmental policy regulations, which are region-specific and target-oriented, allowing us to accurately assess the unintended impacts of the regulations. Through our empirical analysis, we find that the implementation of the environmental regulation policy led to a 9% greater reduction in hog inventories in restricted development areas (treatment group) than in key development areas (control group). And surprisingly, the key development areas have not increased hog production capacity as the policy expected.

Our study also reveals that differences in the impact of environmental regulation not only exist between provinces, but also within provinces, there are no significant differences in regulation. In this regard, we further regressed the regions with typical characteristics into further regression analyses, but the results were not significant. Our existing limitations are mainly due to the difficulty of obtaining relevant data in China, which prevents us from empirically testing the mechanisms we analyzed. However, we believe that this further research and analysis has great scientific value. The next step of our research program is to conduct an in-depth study of these typical regions using different methods to explore whether environmental regulations lead to pollution transfer.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. Announcement on the release of the "Second National Pollution Source Census Bulletin". Available online: http://www.mee.gov.cn/xxgk2018/xxgk/xxgk01/202006/t20200610_783547.html (accessed on 06, 08, 2020).
2. SMITH ED L., SICILIANO G. A comprehensive review of constraints to improved management of fertilizers in China and mitigation of diffuse water pollution from agriculture. Agriculture, Ecosystems & Environment, **209**, 15, **2015**.
3. CAI H.B., CHEN Y., GONG Q. Polluting thy neighbor: Unintended consequences of China′s pollution reduction mandates. Journal of Environmental Economics and Management, **76**, 86, **2016**.
4. BAI Z., JIN S., WU Y., ERMGASSEN E.Z., OENEMA O., CHADWICK D., LASSALETTA L., VELTHOF G., ZHAO J., MA L. China's pig relocation in balance. Nature Sustainability, **2** (10), 888, **2019**.
5. CHEN S., JI C., JIN S.Q. Costs of an environmental regulation in livestock farming: Evidence from pig production in rural China. Journal of Agricultural Economics, **73**, 541, **2021**.
6. ZENG F., YAN L.X., TAN Y. Consequences and Drivers of Differentiated Environmental Regulation Policies on Hog Production in China: A Spatial Econometrics Approach, Frontier of Environment Science, 845147, **2022**.
7. LIU N.N., LO C.W., ZHAN X., WANG W. Campaign-Style Enforcement and Regulatory Compliance. Public Administration Review, **75** (1), 85, **2014**.
8. JIA K., CHEN S. Could campaign-style enforcement improve environmental performance? evidence from china's central environmental protection inspection. Journal of Environmental Management, **245** (1), 282, **2019**.
9. RUNDMO T., IVERSEN H. Risk perception and driving behaviour among adolescents in two Norwegian counties before and after a traffic safety campaign. Safety Science, **42** (1), 1, **2004**.
10. TAY R. The effectiveness of enforcement and publicity campaigns on serious crashes involving young male drivers: Are drink driving and speeding similar? Accident Analysis and Prevention, **37** (5), 922, **2005**.
11. WEDEMAN A. Anticorruption Campaigns and the Intensification of Corruption in China. Journal of Contemporary China, **14** (42), **2005**.
12. LIANG J., LANGBEIN L. Linking anticorruption threats, performance pay, administrative outputs, and policy outcomes in China. Public Administration, **97** (1), 177, **2019**.
13. VAN ROOIJ B. Implementation of Chinese Environmental Law: Regular Enforcement and Political Campaigns. Development & Change, **37** (1), 57, **2010**.
14. KOSTKA G., HOBBS W. Local Energy Efficiency Policy Implementation in China: Bridging the Gap between National Priorities and Local Interests. The China Quarterly, **211**, 765, **2012**.
15. WANG A.L. The search for sustainable legitimacy: environmental law and bureaucracy in China. The Harvard Environmental Law Review, **37** (2), 365, **2013**.
16. KAHN M. E., LI P., ZHAO D.X. Water Pollution Progress at Borders: The Role of Changes in China's Political Promotion Incentives. American Economic Journal: Economic Policy, **7** (4), 223, **2015**.
17. WANG A.L. Explaining environmental information disclosure in China. Ecology Law Quarterly, **44**, 865, **2017**.
18. YANG D.L. China's Illiberal Regulatory State in Comparative Perspective. Chinese Political Science Review, **2** (1), 114, **2017**.
19. HE G.J., WANG S.D., ZHANG B. Watering Down Environmental Regulation in China. The Quarterly Journal of Economics, **135** (4), 2135, **2020**.
20. RAN R. Perverse incentive structure and policy implementation gap in china's local environmental politics. Journal of Environmental Policy & Planning, **15** (1), 17, **2013**.
21. VAN ROOIJ B., ZHU Q.Q., LI N., WANG Q.L. Centralizing Trends and Pollution Law Enforcement in China. The China Quarterly, **231**, 583, **2017**.
22. VAN ROOIJ B., STERN R. E., FURST K. The authoritarian logic of regulatory pluralism: Understanding China's new environmental actors. Regulation & Governance, **10** (1), 3, **2016**.
23. ELIZABETH E. Environmental governance in china: state control to crisis management. Daedalus, **143** (2), 184, **2014**.
24. KOSTKA G. Command without control: The case of China's environmental target system. Regulation & Governance, **10** (1), 58, **2016**.
25. ZHOU X.G., LIAN H., ORTOLANO L., YE Y.Y. A Behavioral Model of "Muddling Through" in the Chinese Bureaucracy: The Case of Environmental Protection. The China Journal, **70**, 120, **2013**.
26. KAMP D. S. Blunt force regulation and bureaucratic control: Understanding China's war on pollution. Governance, **34** (1), 191, **2020**.
27. LI P., LU Y., WANG J. Does flattening government improve economic performance? evidence from china. Journal of Development Economics, **123**, 18, **2016**.
28. ABADIE A., JAVIER G. The Economic Costs of Conflict: A Case Study of the Basque Country. American Economic Review, **93**, 113, **2003**.
29. ABADIE A., DIAMOND A., HAINMUELLER J. Synthetic Control Methods for Comparative Case Studies:

Estimating the Effect of California's Tobacco Control Program. Journal of the American Statistical Association, **105** (490), 493, **2010**.

30. KOSTKA G., NAHM J. Central-Local Relations: Recentralization and Environmental Governance in China. The China Quarterly, **231**, 567, **2017**.

31. ZHANG B., CHEN X.L., GUO H.X. Does central supervision enhance local environmental enforcement? Quasi-experimental evidence from China. Journal of Public Economics, **164**, 70, **2018**.

Appendix

Table A1. Hog production in treatment and control groups.