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Does the Clean Air Action Really Affect Labor Demand in China?

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ABSTRACT

How to balance resources, environment, and economic growth to achieve sustainable development is a challenge for developing countries. In 2013, China implemented a high-stringency environmental regulation, the Clean Air Action, which has effectively controlled air pollution. To explore the economic cost of environmental regulation, this paper investigates the policy effect on employment in the industrial sector. Based on the city-level data and firm-level data, this study applied a quasi-natural experiment for policy evaluation and used the mediating effect model for mechanism analysis. The difference-in-difference estimation results show that environmental regulation has a significant impact on employment. The mechanism analysis verifies that output adjustment, capital input, and green innovation are the main channels by which environmental regulation distresses employment. The findings of this paper could be extended to other countries at a similar stage of development.

KEYWORDS

Clean Air Action, Industrial Sector, Labor Demand, Mediating Effect, Policy Evaluation

1. INTRODUCTION

China's economic and social development in the past 40 years has created a miracle in the world (Ebenstein, 2012; Lin & Zhu, 2020; Lu et al., 2019). In the early stage of Reform and Opening-up, with sufficient labor and loose environmental regulations, China achieved leapfrog development in industry and rapid accumulation of social wealth (Liu et al., 2021). With the increasing emergence of resources and environmental problems, the trade-off between economic development and environmental protection has become a critical issue that plagues many developing countries, including China (Brandi et al., 2020; Ji et al., 2021; J. Li et al., 2020; Lin & Li, 2021).

Resource destruction, environmental pollution, climate change, and other issues caused by extensive development directly threaten human health and survival (Hong et al., 2019; Qin et al., 2017; Ravindra et al., 2019). The effective implementation of environmental regulations will undoubtedly bring huge benefits and social welfare. However, environmental regulations also have direct economic costs, as well as indirect economic costs: the slowdown of economic growth (Y. J. Chen et al., 2018; Jorgenson & Wilcoxen, 1990); curbing investment (Cai et al., 2016; Millimet & Roy, 2016); reduction of industrial activity (Z. Chen et al., 2018; Greenstone, 2002); unemployment (Liu et al., 2017; Raff & Earnhart, 2019) and even affect the country's competitiveness (Ederington, 2010; Peuckert, 2014).

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In particular, the unemployment problem affects the stability of economic and social operations. Even if environmental regulations do not cause permanent unemployment, labor transitions in sectors and regions will bring economic costs to the employees. Especially, low-skilled employees will bear more costs (Walker, 2013), which will seriously influence social welfare and equity.

China's environmental regulations began in the 1980s with the control of industrial dust. But due to the low intensity of the regulations, the minimal impact has been felt on the rapid development of the economy (Alford, 1997; Jin et al., 2016). In the past ten years, haze with fine particulate matter ($\mathrm{PM}_{2.5}$) as the primary pollutant has occurred on a large scale and with high frequency. Since air is one of the most important natural resources for human survival and development, the haze problem will undoubtedly affect residents' health and economic safety. Through epidemiological statistics, Rohde and Muller (2015) found that air pollution in China causes 1.6 million deaths each year, accounting for about 17% of all deaths. Besides, the estimates of Zou et al. (2019) reveal the number of deaths caused by $\mathrm{PM}_{2.5}$ in China was 1.2 million in 2013 and 1.05 million in 2017. Ebenstein et al. (2017) use the geographic discontinuity to design the empirical estimation and found that for every $10\,ug\,/\,m^3$ increase in inhalable particles (PM_{10}) concentration in China, the average life expectancy would decrease by 0.64 years. To control the haze problem, the Chinese government implemented the Air Pollution Prevention and Control Action Plan (referred to as Clean Air Action, CAA) in 2013, which is said to be the most stringent environmental regulatory policy in history (Li & Li, 2020). The goal of the CAA policy is to reduce the concentration of PM_{10} in cities across the country by more than 10% in 2017 compared to 2012, and the concentration of $\mathrm{PM}_{2.5}$ in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta regions to fall by 25%, 20%, and 15%, respectively. Besides, according to requirements, each province needs to set an emission reduction target based on its conditions. Since the generation of haze originates from the economic and social activities of a high-density population, the CAA policy focuses on urban activities and industrial production (Cheng et al., 2019; Zeng et al., 2017). The main measures include industrial structure adjustment, elimination of backward production capacity, reduction of coal combustion, pollution monitoring, cleaner production, and so on.

According to the final assessment of the Ministry of Ecology and Environmental Protection[1], the concentration of PM_{10} in Chinese cities dropped by 22.7% in 2017 compared with 2013, and the emission reduction targets of the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta have also been achieved. A large number of studies have confirmed that the CAA Policy has effectively reduced the concentration of various pollutants, improved air quality, and successfully achieved the policy goals (Feng et al., 2019; Xiao et al., 2020; Xu & Wu, 2020; Zhao et al., 2019). Furthermore, scholars have also demonstrated the benefits of policies from health (Qin et al., 2017; Zheng et al., 2017) and social welfare perspective (N. Li et al., 2019; Zhang et al., 2017). However, to achieve the policy goal, the economic cost paid also needs to be thoroughly evaluated. This paper will explore the CAA policy's economic cost from the perspective of changes in labor demand. China's industrial sector is labor-intensive and provides many jobs (Hanson, 2021; Huang et al., 2016). To cope with environmental regulation, enterprises will optimize production strategies, thereby affecting their labor input. Besides, the impact of environmental regulation on labor demand is not intuitive, the transfer path and influence mechanism need to be explored.

This paper mainly answers two questions: (1) Does the CAA policy impact labor demand in the industrial sector? (2) How does environmental regulation affect employment? The difference-in-difference (DID) framework is constructed to explore the policy effect on labor demand based on the variation in the regulation intensity at different cities. And through the mediation model, this paper analyzes the mechanism of environmental regulation on employment. The researchers found that the CAA policy has led to a significant decline in industrial employment by about 4.59% in cities with stringent environmental regulation. The results of the quasi-natural experiment are still valid after the robustness test. Besides, the policy effect on employment can be disaggregated into two components: output effect and substitution effect, which accounted for 89.36% and 10.64%, respectively.

Compared with the existing literature, the theoretical contributions of this paper will be elaborated from the following four aspects: (1) From the perspective of the impact of environmental regulation on labor demand, this paper investigates the economic cost of the CAA policy, which enriches the relevant research of environmental regulation in China. (2) Combining the quasi-natural experiment and the mediating effect model, this paper clarifies the mechanism of environmental regulation on employment under a unified framework. It also provides empirical evidence for the effectiveness of the mediation effect. (3) The policy evaluation on employment will provide enlightenment for the government to balance economic development and environmental protection. The mechanism analysis offers theoretical bases for policies such as industrial transfer, job placement. (4) Since China is the world's largest industrial and developing country, the findings of this paper can be extended to other emerging and developing countries at a similar stage of development.

The rest of the paper is organized as follows: The next section is the theoretical analysis and research hypothesis. Section 3 will introduce the empirical model and data of this paper. The empirical results will be presented and discussed in Section 4. Finally, the conclusions and policy recommendations are provided in Section 5.

2. CONCEPTUAL FRAMEWORK AND HYPOTHESIS

2.1. Literature Review

Due to the positive correlation between industrial activities and environmental pollution, environmental regulations will inevitably negatively affect industrial activities, reducing labor demand in the industrial sector. According to Greenstone (2002), the 1970 and 1977 Clean Air Act Amendments (CAAA) resulted in a loss of about 75 billion U.S. dollars and 39 billion capital stock in manufacturing in the United States and caused 590,000 unemployment. Based on the changes in pollutant emission reduction requirements in 1990 CAAA, Walker (2011, 2013) designed the quasi-natural experiment to verify the negative impact of environmental regulation on labor. And he measured the economic cost of such labor transitions, about 5.4 billion U.S. dollars. Through the research on the wastewater discharge policy in the Tai Lake Basin in China, Liu et al. (2017) found that high-intensity regulation will decrease approximately 7% in employment in textile printing and dyeing enterprises. What's more, many studies (Curtis, 2018; Henderson, 1996; Kahn & Mansur, 2013; Zhong et al., 2021) have also demonstrated the negative causality from different environmental policies and research perspectives.

However, drawing on the Porter hypothesis (Porter & Van der Linde, 1995), some research (Chan et al., 2013; Cole & Elliott, 2007) offered the opposite view. They believed that environmental regulations can stimulate the improvement of production efficiency to a certain extent, thereby offsetting the pressure of emission reduction and even promoting employment. Ren et al. (2020) investigated China's $S0_2$ emissions trading mechanism and found the market-based environmental policy had positive effects on labor demand. Research on the impact of environmental regulation on employment has not reached a unified conclusion. It can be seen that the difference of environmental policies and the study object will lead to different policy effects on the labor demand.

Research on the CAA policy and labor is limited. Since the time range of X. Li et al. (2020) ended in the second year of the CAA policy, the results show that pollution control has no significant impact on employment. Based on the differences in policy implementation among cities, this paper will use city-level data during 2008-2017 to conduct an effective policy evaluation of the CAA policy by constructing a quasi-natural experiment.

Furthermore, the existing literature does not conduct a comprehensive analysis of the mechanism of environmental regulation affecting labor demand. Berman and Bui (2001) demonstrated that the mechanism of environmental regulation operates via output effect and substitution effect through theoretical analysis. X. Li et al. (2020) and Liu et al. (2021) learned from the theory of Berman and Bui (2001). Using empirical models, they verify the transfer paths from environmental regulation to labor demand, but they lacked quantification of the mechanism. This paper will combine theoretical analysis and empirical research, carry out mechanism analysis, and decompose each transfer channel's contribution under a unified framework.

2.2. Theoretical Hypothesis

First, the researchers use a simplified model to discuss the impact of environmental regulations (R) on labor demand (L), as shown in Equation (1). β is the coefficient of environmental regulation which is the core of our research.

$$L = \alpha + \beta R \tag{1}$$

Since the mechanism between environmental regulation and labor demand is not intuitive, the researchers will analyze labor input changes before and after environmental regulation through the producer theory in the following theoretical analysis. Drawing on the theory of Brown and Christensen (1981), the researchers introduce the quasi-fixed input into the production cost function to represent the enterprise's input for environmental protection. The cost function can be expressed as follows:

$$C = f\left(Y, Z_{1,} \ldots, Z_{n}, P_{1}, \ldots, P_{m}\right) \tag{2}$$

where Y represents the output of the enterprise. Z represents the quasi-fixed inputs. P represents the price of variable inputs. It should be noted that both quasi-fixed and variable inputs can include capital, technology, and other factors[2]. Variable inputs refer to inputs used for production, which are subject to cost minimization constraints. But quasi-fixed inputs are used for exogenous environmental regulation, which are not constrained by cost minimization.

Referring to Berman and Bui (2001), the researchers take the partial derivative of Equation (2) and get the linear labor demand function, as follows:

$$L = \rho_{y} Y + \sum_{j=1}^{n} \mu_{j} Z_{j} + \sum_{i=1}^{m} \delta_{i} P_{i} + \theta \tag{3}$$

Without considering environmental protection, when enterprise activities (Y) increase, expansion and reproduction require more inputs, and labor demand (L) will increase. The ρ_{y} is assumed to be a positive value. Therefore, the researchers propose:

Hypothesis 1: Labor demand is positively correlated with industrial activity.

The relationship (μ) between labor demand and the quasi-fixed inputs (Z) for environmental protection cannot be determined. The introduction of clean technologies and the installation of advanced equipment will increase the demand for high-skilled employees on the one hand, and reduce the demand for low-skilled employees for pollution-related production on the other. So, the researchers propose:

Hypothesis 2a: Labor demand is positively correlated with other inputs.
Hypothesis 2b: Labor demand is negatively correlated with other inputs.

Next, the researchers take the partial derivative of the labor demand equation with respect to environmental regulation, and obtain Equation (4), as follows:

$$\frac{dL}{dR} = \rho_y \frac{dY}{dR} + \sum_{j=1}^{n} \mu_j \frac{dZ_j}{dR} + \sum_{i=1}^{m} \delta_i \frac{dP_i}{dR} = \beta \tag{4}$$

Without loss of generality, the researchers assume that the factor market in which the firm operates is perfectly competitive. Therefore, the price of variable inputs is not affected by environmental regulation, i.e., $\frac{dP}{dR} = 0$. Under environmental regulation, the enterprise could optimize labor input by adjusting output and quasi-fixed inputs, namely output effect and substitution effect, respectively. Considering that capital substitution and technology substitution are common measures in industrial production, and the availability of data in the empirical analysis, the researchers specify quasi-fixed inputs as capital input (Z_K) and technology input (Z_T). Equation (4) can be written as:

$$\frac{dL}{dR} = \rho_y \frac{dY}{dR} + \mu_1 \frac{dZ_K}{dR} + \mu_2 \frac{dZ_T}{dR} = \beta \tag{5}$$

Intuitively, pollution control will curb industrial output, so $\frac{dY}{dR}$ is assumed to be negative. However, according to the Porter hypothesis (Porter & Van der Linde, 1995), environmental regulation will also stimulate production efficiency, which in turn stimulate output increases, i.e. $\frac{dY}{dR} > 0$. Therefore, the researchers propose:

Hypothesis 3a: Environmental regulation will decrease industrial activities and reduce output.
Hypothesis 3b: Environmental regulation will stimulate production efficiency and increase output.

Under environmental regulation, the enterprise needs to shift from the traditional extensive production with high pollution and high emission to clean production, and R&D investment will increase, so $\frac{dZ_T}{dR}$ is supposed to be positive. The changes in the capital investment of the enterprise cannot be determined. The enterprise may reduce its investment in traditional equipment or even eliminate backward production capacity. To reduce pollution emissions, the enterprise may introduce high-efficiency production equipment and install pollution abatement facilities. Above all, the researchers are uncertain whether $\frac{dZ_K}{dR}$ is positive or negative. Finally, the researchers propose:

Hypothesis 4a: Environmental regulation will reduce other inputs.
Hypothesis 4b: Environmental regulation will increase other inputs.

3. RESEARCH DESIGN

3.1. Empirical Framework

Based on the CAA policy as a shock to construct a quasi-natural experiment, this paper explores the impact of environmental regulation on labor demand in the industrial sector. The CAA policy was implemented from 2013 to 2017[3]. This paper sets the research scope to five years before and after the CAA policy launch (2008-2017). Due to the heterogeneities in economic development and air quality, different regions have different emission reduction targets during the CAA policy period, and thus the intensity of environmental regulations differs. Considering the variations of environmental regulation in time and cities, this paper constructs a DID model to evaluate the policy effects on labor demand, as follows:

$$ln(Labor_{c,y}) = \beta_0 + \beta_1 \times CAA_c \times Post_y + \boldsymbol{X}' \times {}^{2} + \eta_C + \eta_y + \varepsilon_{c,y} \tag{6}$$

where $Labor_{c,y}$ represents the labor demand of the industrial sector in region c at time y. CAA_c is the city dummy variable: When a city has a high emission reduction target and faces stringent environmental regulation, it will be assigned to the experimental group, and $CAA_c = 1$; while a city with lax regulation stringency will be assigned to the control group and $CAA_c = 0$. The year dummy variable $Post_y = 1$ if $y \geq 2013$; and $Post_y = 0$ if $y < 2013$. $\boldsymbol{X}$ represents the control variables. To control the influences of unobservable region and time factors on labor demand, the researchers control the city and year fixed effects in the DID model, denoted by η_C and η_y, respectively. $\varepsilon_{c,y}$ is the error term.

β_1, as the coefficient of the interaction term of CAA_c and $Post_y$, measures the policy effect of the CAA policy on employment, which can be expressed explicitly by Equation (7):

$$\beta_1 = \left\{E\left[\ln(Labor_{c,y}) \mid CAA_c = 1, Post_y = 1\right] - E\left[\ln(Labor_{c,y}) \mid CAA_c = 1, Post_y = 0\right]\right\}$$

$$-\left\{E\left[ln(Labor_{c,y}) \mid CAA_c = 0, Post_y = 1\right] - E\left[ln(Labor_{c,y}) \mid CAA_c = 0, Post_y = 0\right]\right\} \tag{7}$$

Since the CAA policy was implemented nationwide after 2013, the selection of the experimental group and the control group cannot simply be based on whether a city implements the policy. Referring to the research of Li et al. (2020b) on the same issue, the researchers divide the cities into experimental group and the control group according to each province's emission reduction target[4]. In this paper, cities with a reduction target of 20% or more are set as the experimental group, and cities with a reduction target of less than 20% are set as the control group. The selection of the experimental group and the control group are shown in Table 1. The air quality and economic activities before the environmental regulation are also shown in Table 1. It can be seen that the average $\mathrm{PM}_{2.5}$ concentration of the cities in the experimental group is higher than that of the control group's cities; air quality was worse in the experimental group. Also, from the perspective of the share of employment in the secondary industry, the average proportion of cities in the experimental group is significantly higher than that in the control group, indicating that the experimental group's industrial sector is more active. After implementing the CAA policy, the experimental group cities will face higher pressure for pollution abatement and stringent regulation, and the CAA policy is supposed to have a stronger impact on employment in the industrial sector.

3.2. Mediation Model

In mechanism analysis and transfer path exploration, the mediating effect model has a wide range of applications (Alan et al., 2018; Cutler & Lleras-Muney, 2010; Judd & Kenny, 1981; Lin & Ge, 2020). To investigate how the CAA policy affects employment in the industrial sector, this paper designs a mediating effect model, as follows:

Table 1. The comparison of experimental group and control group

	Experimental group (59)	Control Group (213)
Cities	3 municipalities (Beijing, Tianjin, Shanghai) and 56 prefecture-level cities in Hebei, Shanxi, Jiangsu, Zhejiang, and Shandong provinces.	1 municipality (Chongqing) and 212 prefecture-level cities in Guangdong, Inner Mongolia, Henan, Shaanxi, Qinghai, Xinjiang, Hubei, Gansu, Liaoning, Jilin, Anhui, Jiangxi, Hunan, Sichuan, Ningxia, Heilongjiang, Fujian, Guangxi, Guizhou, Hainan, Yunnan, and Tibet provinces.
Emission reduction target	$\geq 20\%$	$< 20\%$
Average $\mathrm{PM}_{2.5}$ concentration in 2012	53.20 ug / m^3	42.60 ug / m^3
Average proportion of employees in the secondary industry in 2012	51.30%	42.99%

Note: i) Since China's $\mathrm{PM}_{2.5}$ monitoring didn't cover 366 cities until 2016, the gridded $\mathrm{PM}_{2.5}$ concentration data for each city is derived from the Atmospheric Composition Analysis Group (http://fizz.phys.dal.ca/~atmos/martin/?page_id=140). ii)The employment data at the city level is obtained from the China City Statistics Yearbook.

$$ln(Labor_{c,y}) = \beta_0 + \beta_1 \times CAA_c \times Post_y + \beta_2 M_{c,y} + \boldsymbol{X'} \times {}^{2} + \eta_C + \eta_y + \varepsilon_{c,y} \tag{8}$$

where $M_{c,y}$ is the mediating variable. According to the theoretical derivation in Section 2.2, environmental regulation may affect labor demand through the output effect and the substitution effect. The researchers explored the mediating effect by comparing the changes of the interaction term coefficient β_1 before and after adding the mediators. For example, the researchers add the industrial output to Equation (7) as the transfer channel. If the coefficient β_2 is significant and the coefficient β_1 decreases, it indicates that environmental regulation decreases the labor demand by reducing industrial activities, and there exists the output effect. Capital input and green innovation input are used as mediators to verify the substitution effect, and the discussion is similar to the above.

To ensure the accuracy of the research, the researchers need to verify the existence and direction of the transfer path. Therefore, the researchers have to explore the causal relationship between the CAA policy and mediator before the mediation analysis. Equation (9) is expressed as follows:

$$M_{c,y} = \gamma_0 + \gamma_1 \times CAA_c \times Post_y + \boldsymbol{X'} \times {}^{3} + \eta_C + \eta_y + \varepsilon_{c,y} \tag{9}$$

3.3. Variables and Data

To analyze the CAA policy impact on labor demand, the researchers conduct a city-level panel dataset from 2008 to 2017. The dependent variable labor demand ($Labor$) is measured by the number of employees in each city's industrial sector at the end of the year. According to the theoretical analysis above, the researchers treat the output effect and substitution effect as the mechanism effect to verify the policy effect on labor demand. Referring to relevant studies (X. Li et al., 2020; Liu et al., 2021; Zhang et al., 2019), the mediating variables are chosen as follows: Industrial output ($Output$) is measured by the GDP of the secondary industry, indicating urban industrial activity. Capital input ($Capital$) is measured by investment in fixed assets in the industrial sector[5], indicating capital investment in the industrial sector. Technological progress is pivotal for sustainable development, and green technological innovation refers to the innovative activities among them (Chen et al., 2020; Song et al., 2019). The patent is wildly sued as an indicator which can reflect technological innovation (Jia et al., 2021), and green patents[6] are a recognized form of green innovation and an important way for enterprises to invest in technology for cleaner production (Hirshleifer et al., 2013; Ley et al., 2016). Therefore, the researchers use the share of green invention patent application data to the total to indicate technology substitution ($Innovation$)[7].

To reduce the impact of other factors on labor demand, the researchers choose the following variables as control variables: (1) Population is the source of labor. The scale of the city will affect the economic agglomeration (Lin & Zhu, 2019; Yu et al., 2019). $Population\,density$, as the indicator, is measured by the number of people per unit area. (2) The degree of openness ($Opening$) will also affect the green development of the city, which in turn will have an impact on employment under environmental regulation (Taskin & Zaim, 2001; Zeng & Zhao, 2009). The researchers use the ratio of total imports and exports to the city's GDP for measurement. (3) $Government\,scale$ is measured by the proportion of government fiscal expenditure in local GDP, reflecting the degree of government intervention in the market (Zhou et al., 2018). (4) $Human\,resource$ is measured by the share of college students in the total population, which captures the reserve of high-skilled talents and the city's innovation potential (Song et al., 2020). (5) To meet the emission reduction requirements, industrial enterprises often carry out capital technology substitution and industrial upgrading through financing, while finance development ($Finance$) reflects the credit constraints for industrial enterprises (Aghion et al., 2012; Zhang & Zheng, 2019). The researchers use the ratio of the sum of deposits and loans to the city's GDP for measurement.

Due to data limitations, this paper sets the research scope to 272 prefecture-level cities (including 4 municipalities). The data comes from the China City Statistical Yearbook. The missing data in some years is supplemented by consulting provincial-level and city-level statistical yearbooks and websites of the local Statistical Bureau. Patent data comes from the State Intellectual Property Office. By collecting the patent data and the information of the applicant enterprises, the researchers aggregate the firm-level data to the city-level. Besides, to exclude the influence of price factors, all nominal indicators in this paper are converted to 2008. The main statistical indicators of each variable are shown in Table 2.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Estimates of Policy Evaluation

Firstly, this paper verifies the impact of the CAA policy on labor demand in the industrial sector. The benchmark results based on Equation (6) are shown in Table 3. The results in column (1) show that after controlling for time and region fixed effects, the interaction term's coefficient is significantly negative. The DID estimate shows that after implementing the CAA policy, industrial employment in regions with harsher reduction requirements has dropped significantly compared to cities with loose environmental regulation. After controlling the time-varying region characteristics that may affect employment, there is no significant change in the results, as shown in column (2). The point elasticity estimate shows that the CAA policy will lead to a significant drop of 4.59% in employment in regions with high-stringency regulation[8].

Table 2. Summary statistics

Variable	Full sample			Experimental sample			Control sample		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Labor (10 thousand persons)	2720	25.721	36.942	590	43.389	44.653	2130	20.828	32.876
Output (100 million CNY)	2720	890.595	1115.673	590	1567.731	1515.250	2130	703.031	890.063
Innovation (ratio)	2720	0.124	0.069	590	0.115	0.039	2130	0.126	0.075
Capital (100 million CNY)	2720	533.620	610.573	590	845.894	693.374	2130	447.122	555.514
Population density ($\mathrm{person} / \mathrm{km}^2$)	2720	442.828	525.319	590	610.539	491.160	2130	396.373	525.111
Opening (ratio)	2720	0.186	0.317	590	0.297	0.354	2130	0.155	0.299
Government scale (ratio)	2720	0.188	0.101	590	0.140	0.053	2130	0.201	0.107
Human resource (ratio)	2720	0.016	0.020	590	0.019	0.021	2130	0.016	0.020
Finance (ratio)	2720	2.243	1.134	590	2.550	1.211	2130	2.157	1.097

4.2. Robustness Check

4.2.1. Event Study

The parallel trend test is an important premise for constructing the DID model. In other words, the experimental group and the control group should have the same trend before implementing the CAA policy. Only when the parallel trend test is satisfied, the DID estimation can explain the significant difference between the experimental group and the control group caused by the policy, rather than existed before the policy. Referring to Cai et al. (2016) and Li et al. (2016), the researchers construct the event study as follows:

$$ln(Labor_{c,y}) = \beta_0 + \sum_{j=2009}^{2017} \beta_j \times CAA_c \times Year_j + \boldsymbol{X}' \times {}^{2} + \eta_C + \eta_y + \varepsilon_{c,y} \tag{10}$$

where $Year_j$ is a series of time dummy variables, representing each year during 2009-2017. Time category 2008 was not included, so the coefficient β_j is estimated relative to 2008.

The results of the event study are shown in Figure 1. It can be seen that before 2013, the trend of the coefficient of the interaction of $CAA_c \times Year_j$ is uncertain, and there is no significant difference from 0. The parallel trend test is verified, and the DID results in Section 4.1 are robust. What's more, the event study results also clarified the dynamic effects of the CAA policy. As shown in Figure 1, after the coefficient β_j briefly rose to 0 in 2014, the plot shows a clear downward trend, and β_{2017} was significantly negative at 5% significance. The results show that in the initial stage of the CAA

Table 3. Main results of policy evaluation

Dependent Variable:		
	(1)	(2)
$CAA_c * Post_y$	-0.033*	-0.047**
	(0.019)	(0.020)
$ln\left(Population\ density_{c,y}\right)$		0.108
		(0.096)
$Opening_{c,y}$		-0.025
		(0.065)
$Government\ sacle_{c,y}$		-0.799***
		(0.172)
$Human\ resource_{c,y}$		2.152
		(1.811)
$Finance_{c,y}$		-0.052***
		(0.020)
Region fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
Observations	2720	2720
R^2	0.953	0.955

Note: i) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. ii) Heteroskedasticity-robust standard errors are shown in parentheses.

policy, environmental regulation has no obvious impact on labor demand, consistent with X. Li et al. (2020). However, with the effective implementation of the environmental regulation, the impact of pollution control on employment gradually increased, and the negative policy effect was concentrated in the final stage.

4.2.2. Placebo Test

Referring to Song et al. (2020), this paper designs a placebo test to verify that the policy effect on labor demand is indeed caused by the CAA policy implemented in 2013. The researchers choose different periods before 2013 and randomly assume that environmental regulation occurs in a certain year within the period. Then the DID estimation was conducted again to evaluate the counterfactual CAA policy, and the results are shown in Table 4. All interaction coefficients of models (1)-(10) are not significant at the 10% level, verifying that the significant decline in employment is indeed caused by the CAA policy implemented in 2013. Above all, the empirical results in Section 4.1 have been tested for robustness and are valid.

4.3. Mechanism Analysis

4.3.1. Transfer Channels

After clarifying the negative impact of the CAA policy on industrial employment, the researchers will explore the policy's mechanism. First, this paper will verify the transfer path. As analyzed in

Figure 1. Lags, leads, and time trends[9]

Table 4. Counterfactual test

Dependent Variable:				
	Time period:	Time period:	Time period:	Time period:
	2008-2010	2008-2011	2008-2012	2008-2013
Counterfactual policy in 2009	(1)	(2)	(3)	(4)
	-0.002	0.003	0.008	-0.004
	(0.015)	(0.018)	(0.020)	(0.025)
Counterfactual policy in 2010		(5)	(6)	(7)
		0.006	0.008	-0.003
		(0.014)	(0.015)	(0.020)
Counterfactual policy in 2011			(8)	(9)
			0.008	-0.007
			(0.017)	(0.021)
Counterfactual policy in 2012				(10)
				-0.008
				(0.027)

Note: i) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. ii) Heteroskedasticity-robust standard errors are shown in parentheses. iii) Control variables, region fixed effect and time fixed effect are all included in the estimation of model (1)-(10).

the above section, the potential channels are that environmental regulation affects employment by affecting industrial output and substitutes (capital and green innovation) inputs. Based on Equation (9), the researchers will verify the existence and direction of the transfer path, and the results are shown in Table 5.

Table 5. Check on transfer channels

Dependent Variable:	(1) $Innovation_{c,y}$	(2) $ln\left(Capital_{c,y}\right)$	(3) $ln\left(Output_{c,y}\right)$
$CAA_c * Post_y$	0.019***	-0.043**	-0.110***
	(0.003)	(0.020)	(0.007)
$ln\left(Population\ density_{c,y}\right)$	0.045*	-0.092	-0.015
	(0.024)	(0.113)	(0.063)
$Opening_{c,y}$	0.002	0.006	0.052**
	(0.016)	(0.056)	(0.021)
$Government\ scale_{c,y}$	-0.075	0.254	-0.426***
	(0.053)	(0.250)	(0.117)
$Human\ resource_{c,y}$	-0.289	2.247	4.152***
	(0.303)	(2.470)	(1.322)
$Finance_{c,y}$	0.010**	-0.355***	-0.161***
	(0.004)	(0.042)	(0.021)
Region fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
Observations	2720	2720	2720
R^2	0.436	0.942	0.991

Note: i) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. ii) Heteroskedasticity-robust standard errors are shown in parentheses.

In column (1) of Table 5, the researchers can verify the impact of environmental regulation on technology substitution. The interaction term's coefficient indicates that the CAA policy will significantly increase the green innovation input in the industrial sector, which is consistent with the findings of Tanaka et al. (2014) and Cui et al. (2018). To transform to clean production and reduce pollution emissions, the industrial sector will increase R&D investment, especially R&D investment in green innovation. Hypothesis 4b is verified when the alternative input is the investment in green innovation.

The results in column (2) show that environmental regulation negatively impacts capital input. According to the CAA policy's specific measures, highly pollution-emitting and energy-consuming industrial sectors were required to limit new capacity and accelerate the elimination of backward capacity. Although, the industrial sector will reduce pollutant emissions by replacing efficient production equipment and installing pollutant treatment facilities (Liu et al., 2021). On the whole, capital investment in the industrial sector decreased under environmental regulation. When the substitute is capital input, Hypothesis 4a is verified.

According to the results shown in column (3), the coefficient of DID is significantly negative, indicating that the CAA policy restrained industrial activities and caused industrial output to decline. Hypothesis 3a is verified. The point elasticity estimate shows that during the CAA policy period, the industrial added value in areas with more stringent environmental regulation fell by 10.42%. In the research of X. Li et al. (2019), they used the program evaluation method to find that the industrial added value of the Beijing-Tianjin-Hebei region fell by 6.65% in the first two years of the CAA policy. The quantitative difference may lie in the time range (our paper examines the whole period of the policy), the selection of the experimental group (except for the Beijing-Tianjin-Hebei region, the experimental group in this paper also includes Shanghai, Jiangsu, Zhejiang, and Shandong), and the empirical method.

4.3.2. Mediating Effect

After confirming three transfer channels, the researchers analyze environmental regulation's influence mechanism on labor demand through the mediating effect model. According to Equation (8), the researchers add mediators one by one, and the change in the coefficient of the interaction term will reflect the mediating effect caused by the transfer channel. The empirical results of the mechanism analysis are shown in Table 6.

For an intuitive comparison of the results, the researchers add the benchmark regression results in column (1) of Table 6, which are just the results of column (2) of Table 3. Furthermore, the researchers add green innovation input as the mediator in the policy evaluation model. First, the researchers found that green innovation input is negatively correlated with labor demand, and Hypothesis 2b has been verified. Secondly, with the addition of the transfer path, the coefficient of the interaction term increases significantly. Combining the results in column (1) of Table 5 and column (2) of Table 6, it can be seen that environmental regulation has a technology substitution effect on labor demand. Environmental regulation forces the industrial sector to increase investment in green innovation, and clean production eliminates workers in traditional production processes. After controlling the negative policy effect on labor demand through technology substitution, the DID estimate's coefficient has risen significantly. In detail, the policy effect on the labor demand through promoting green innovation is -0.003.

Next, the researchers continue to add capital input as another mediator. The results in column (3) show a complementary relationship between capital input and labor demand, and Hypothesis 2a has been verified. Besides, the addition of a new transfer channel will cause the interaction term's coefficient to continue to rise. Combining the results in column (2) of Table 5 and column (3) of Table 6, the researchers find that the CAA policy will reduce capital investment, and employment in the relevant industry chain will decline. Specifically, the impact of environmental regulation on labor demand through reducing capital input is -0.006.

Finally, the researchers verify the output effect of the policy by adding the variable $Output$. According to the producer theory, if both output and input are considered simultaneously, the endogenous problem will be caused by the reverse causality problem, and the estimates will be biased. Therefore, the researchers will use the industrial output in the last year as an instrumental variable to solve the potential endogenous problem, and the results are shown in column (4). The F statistic in the first stage is greater than 10, which conforms to the empirical rule of IV estimation. From the coefficients, the researchers can see the industrial output and labor demand are significantly positively correlated, and Hypothesis 1 has been verified. The further increase in the coefficient of $CAA_c * Post_y$ indicates that environmental regulation decreased labor demand by restraining industrial activities. In detail, the policy effect on labor demand through restraining industrial output is -0.038. It is worth noting that after controlling all the three mediators, the interaction term's coefficient is close to 0,

Table 6. Results of mechanism analysis

Dependent Variable:				
	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	IV
$CAA_c * Post_y$	-0.047**	-0.044**	-0.038*	-0.000
	(0.020)	(0.020)	(0.020)	(0.024)
$Innovation_{c,y}$		-0.177**	-0.149*	-0.139*
		(0.081)	(0.078)	(0.076)
$ln\left(Capital_{c,y}\right)$			0.142***	0.066*
			(0.021)	(0.035)
$ln\left(Output_{c,y}\right)$				0.382***
				(0.139)
$ln\left(Population\ density_{c,y}\right)$	0.108	0.116	0.128	0.126
	(0.096)	(0.096)	(0.092)	(0.087)
$Opening_{c,y}$	-0.025	-0.025	-0.026	-0.045
	(0.065)	(0.065)	(0.066)	(0.066)
$Government\ scale_{c,y}$	-0.799***	-0.812***	-0.847***	-0.664***
	(0.172)	(0.170)	(0.158)	(0.157)
$Human\ resource_{c,y}$	2.152	2.101	1.789	0.379
	(1.811)	(1.824)	(1.676)	(1.697)
$Finance_{c,y}$	-0.052***	-0.050**	-0.000	0.034*
	(0.020)	(0.020)	(0.020)	(0.020)
Region fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Observations	2720	2720	2720	2720
R^2	0.955	0.955	0.956	0.095
First stage				
Instrumented variable: $\ln\left(\mathrm{Output}_{c,y}\right)$. Instrument: $\ln\left(\mathrm{Output}_{c,y-1}\right)$.				
Coefficient on instrument				0.494***
F statistic on instrument				10.232

Note: i) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. ii) Heteroskedasticity-robust standard errors are shown in parentheses.

and it is not significant. It can be seen that the transfer paths of green innovation input, capital input, and industrial output play a complete mediating effect in the policy effect on employment.

4.3.3. Analysis Based on The Bootstrap Method

By comparing the change in the interaction term's coefficient, the researchers preliminarily discussed the policy effect on employment through different channels in the above subsection. However, the coefficients and their significances may change with the different order of adding mediators. To test the existence of the mediating effect and measure the indirect effect of different channels, the researchers will use the non-parametric percentile Bootstrap method[10] for mechanism analysis.

The steps of the Bootstrap method are shown as: (1) Random repeated sampling with replacement based on the original sample. (2) Calculating the estimated value of the mediating effect based on the drawn sample. (3) Repeat the above steps B times (B=500 in this paper), then use the mean of the B times mediating effect estimates as the point estimates of the mediating effect, sort them by numerical value, and estimate 95% percentile confidence interval with the 2.5th percentile and the 97.5th percentile of the mediating effect (Preacher et al., 2007). Furthermore, Preacher and Hayes (2008) and Taylor et al. (2008) pointed out that the Bootstrap method with the bias-corrected confidence interval is more effective.

The results based on the Bootstrap method are shown in Table 7. The average effect of environmental regulation on employment through influencing green innovation input, capital input, and industrial output is -0.002, -0.003, and -0.042, respectively. In terms of statistical test significance, the indirect effects of green innovation and capital investment are both significant in the bias-corrected Bootstrap method, and the indirect effect of output is significant in both percentile and bias-corrected Bootstrap methods. However, the direct effect of environmental regulation on employment is insignificant, and the magnitude is too small to be ignored. From the perspective of each transmission mechanism's share to the overall policy effect, the output effect is the main transfer channel, and the mediating effect accounts for 89.36%. Technology substitution effect and capital substitution effect account for 4.26% and 6.38%, respectively[11].

Table 7. Mediating effect based on the Bootstrap method

	Coefficient	Bias	Std. Dev.	95% Conf. Interval	
Indirect effect (Innovation)	-0.002	0.000	0.002	[-0.006, 0.000]	(P)
				[-0.006, -0.000]	(BC)
Indirect effect (Capital)	-0.003	-0.000	0.002	[-0.008, 0.000]	(P)
				[-0.008, -0.000]	(BC)
Indirect effect (Output)	-0.042	0.002	0.016	[-0.066, -0.005]	(P)
				[-0.066, -0.003]	(BC)
Direct effect	-0.000	-0.004	0.027	[-0.057, 0.046]	(P)
				[-0.050, 0.048]	(BC)

Note: (P): percentile confidence interval; (BC): bias-corrected confidence interval.

5. CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Main Conclusions

This paper designs a quasi-natural experiment to explore the economic cost of the CAA policy from the perspective of employment changes. To cope with the increasingly prominent environmental problems, especially air pollution, the Chinese government has shifted its focus from economic development to sustainable development. This paper found that the CAA policy caused employment in the industrial sector to drop by about 5%. The negative impact is undeniably significant in the last year of the CAA policy, which is closely related to the vigorous promotion of regulatory measures in the final stage to achieve emission reduction targets.

To further analyze the mechanism and transfer path of the CAA policy on employment, this paper uses the mediating effect model to verify that output adjustment, capital input, and green innovation are the main channels through which environmental regulation affects employment. And the output effect plays a dominant role, accounting for 90% of the overall effect. In other words, environmental regulation mainly affects employment by suppressing production.

5.2. Policy Implications

Based on the above conclusions, the researchers put forward the following four policy recommendations:

(1) Environmental regulation and economic costs: The industry sector played a pivotal role in China's rapid development period. Relying on the demographic dividend and extensive development, China's industrial sector has created many jobs and brought immense social wealth. The CAA policy is a top-down environmental regulation, and the policy's implementation is a challenge for the local government. Faced with stringent environmental regulation, cities often pay a high economic cost as local officials make a trade-off between economic development and environmental protection (Y. J. Chen et al., 2018). In the formulation of future environmental and climate policies, governments at all levels should fully consider development trends and environmental quality, and then specify policy targets and measures. The Chinese government has pledged to achieve carbon peak by 2030 and carbon neutral by 2060. To achieve the policy goals and ensure the stable operation of the economy and society, it is necessary to formulate specific emission reduction targets and detailed abatement measures at different stages and regions.

(2) Environmental regulation and labor demand: Industrial upgrading and the transfer of labor-intensive industries will inevitably affect the labor force, and the government needs to ensure the labor force while implementing environmental regulations. According to the study of Walker (2013), employment transitions caused by environmental regulation mainly occur among sectors, which means employees shift from heavily polluting sectors to sectors with lax regulation. The government needs to ensure the proper placement of the unemployed and provide certain support to alleviate the social impact caused by the concentrated unemployment of the affected sectors. Besides, it is necessary to establish a complete policy to provide retraining and entrepreneurial assistance for low-skilled labor. Due to the heterogeneous intensity of environmental regulation in various regions, labor-intensive industries will shift to China's central and western regions (Hanson, 2021). The central government needs to help the central and western regions to undertake industrial transfer and optimize the spatial distribution of productive forces. For the surplus labor in the old industrial cities in the east, the local government should optimize the regional industrial structure and actively promote employees' transformation.

(3) The guiding role of the government: In the face of the most stringent environmental regulation, it is difficult for the industrial sector to achieve clean production through transformation and upgrading in the short term. Enterprises can only reduce industrial activities and even face forced shutdowns by the local government (X. Li et al., 2019). Considering the rapid development of

green technology in China and the active practices of the CAA policy in various regions (Boon et al., 2020; Losacker & Liefner, 2020), the central government and local governments should effectively guide environmental innovation and reduce the resistance of regulation to economic growth. The Chinese government mainly uses command-and-control measures in environmental regulation but lacks market-based measures (Xie et al., 2017). Given that market-based measures can stimulate enterprise innovation at lower economic costs to achieve effective emission abatement and green transformation (Jaffe & Palmer, 1997; Shen & Wang, 2019), the government should develop adaptive policy innovations, improve the mechanism design, and accelerate the establishment of pollutant emission trading markets.

(4) China's experiences of environmental regulation: During the rapid development period of nearly 40 years, China is in the middle and lower reaches of the global industrial chain. World factory has become the most obvious label for China. As China's economy accelerates its transformation, labor-intensive industries are gradually shifting to other emerging economies (such as Vietnam, India, etc.). To coordinate the relationship among resource utilization, environmental protection and economic development, China's experience will provide references and inspirations for countries in the same situation.

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ENDNOTES

1 To see the official document, you can visit https://www.mee.gov.cn/gkml/sthjbgw/qt/201806/t20180601_442329.htm.

2 Without loss of generality, the researchers believe that labor input is only included in the variable input to simplify the expression of the model.

3 The CAA policy ended in 2017, after which a series of new environmental regulations for air pollution control have been implemented.

4 According to the requirements of the central government, each province stated Responsibility for Air Prevention and Control Target in 2014. The reduction target focuses on the annual average PM concentration of each province in 2017 compared with that in 2012. Data Source: https://www.mee.gov.cn/home/ztbd/rdzl/dqst/mbzrs/index_1.shtml

5 Due to data limitations, the researchers are unable to obtain data on the fixed asset investment for pollution abatement. This paper uses city-level fixed-asset investment to measure capital input. In the analysis of the empirical results, the relevant explanations will be distinguished.

6 By matching the patent number published by the State Intellectual Property Office with the list of green patent classification numbers published by the World Intellectual Property Organization, green patents can be identified.

7 Due to the continuous increase in R&D investment and policy support, patent applications in China have shown explosive growth in the past 20 years. To highlight the investment in green innovation, the researchers use the percentage of green invention patent applications in all invention patent applications to measure green innovation input.

8 Equation $e^{\beta_1} - 1$ was used to estimate the elasticity of the semi-log model.

9 The figure shows coefficients and 95% confidence intervals of policy effect on labor demand.

10 The authors thank the reviewer for the suggestion on the Bootstrap method.

11 $4.26\% = \left(-0.002\right) / \left(-0.047\right); 6.38\% = \left(-0.003\right) / \left(-0.047\right); 89.36\% = \left(-0.042\right) / \left(-0.047\right).$

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