Disaster Lurks Within Good Fortune: Unintended Environmental Consequence of Minimum Wage in China

This paper investigates how firm's factor structure affects its pollution emissions, based on the exogenous differences of county-level minimum wage policies in China from 1999 to 2011. We find that the rise of minimum wage significantly increases manufacturing firms' COD emission, and the results hold up for a battery of robustness tests including different specifications. The unintended pollution effect is particularly stronger in non-state-owned enterprises, labor-intensive industries, and regions with strong labor protection. Two plausible channels might include: (1) rising minimum wage raises firms' labor cost, thus forcing firms to choose capital to replace labor companion larger energy consumption, and (2) rising minimum wage exacerbates firm's financial constraints, and inhibits firm's innovation. Overall, this study highlights the negative consequence of minimum wage on environment is a critical side effect, which must be considered to achieve coordinated labor and environment protection.

Keywords: Minimum wage; Environmental performance; Factor substitution; Factor structure; China

1. Introduction

Firm's structure and cost of production factors not only affect its production performance but also affect its pollution emission through factor restructuring. Early studies reveal the economic structure dominated by heavy industry and the factor structure with high capital dependence are the main reasons for the rapid increase in pollution (Grossman and Krueger, 1991; Levinson, 2009). However, the path of pollution reduction from the perspective of firm's traditional element structure optimization is still unexplored. The existing research mainly focuses on the impact of technical factors (such as technological progress and green innovation), market factors (such as the carbon market, market competition, and trade), and institutional factors (such as environmental regulation and environmental policies) (Chen et al., 2018; Shapiro and Walker, 2018; Greenstone et al., 2022; He et al., 2020; Fan et al., 2021). How could the relationship between labor and capital, the two primary inputs of production, affects firms' pollution emissions still needs further discussion and evaluation.

Discussion on the relationship between firm's factor structure and pollution emission is often plagued by endogeneity problems. On the one hand, the level of pollution emission will affect firms' factor structure and cost, since an extensive body of research has pointed out that pollution will directly affect workers' health and labor productivity and accelerate labor depreciation (Chang et al., 2019; He et al., 2019; Fu et al., 2021). On the other hand, the problem of missing variables is another obstacle, since environmental regulations could simultaneously affect both firm's pollution emissions and factor allocation. Therefore, it is particularly critical to find an effective entry point to identify the relationship.

Minimum wage, a policy tool which directly affects a firm's structure and cost of production factors, we suppose this exogenous change of labor cost is suitable for investigation. Generally, minimum wage policy has triggered already-heated debates on its direct employment effect and successively economic effects on firm-level financial performance, such as profitability, productivity, export behavior, and region-level entrepreneurship, while mostly without reaching a final consensus (Riveros et al., 1992; Card and Kruger, 1994; Dube et al., 2010; Draca et al., 2011; Gan et al., 2016; Mayneris et al., 2018; Cengiz et al., 2019; Geng et al., 2022; Kong et al., 2021; Neumark and Corella, 2021). More and more scholars renovate previous awareness and perceptions of minimum wage policies, including revisiting the disputable employment effect and extensive crowing-out economic impacts (Geng et al., 2022). Conceptually, we suppose minimum wage policy although encourages firms to better protect workers, while at the same time, the rise of labor costs would also influence firms' factor structure and production activity. On the one hand, firms may avoid the impact of rising labor costs on production and operation by replacing labor with capital and rising labor cost will tighten firm's financial constraints. In the meanwhile, firm's strategies to cope with the rising labor costs can greatly affect its pollution emission behavior.

In this study, we investigate how rising labor cost impact on firm's emission behaviors, based on the significant variations in minimum wage policies across counties in China. To the best of our knowledge, we are the first literature investigating this relationship from the micro perspective of firms. Specifically, we construct an extensive firm-county-year panel dataset of median and large manufacturing firms from multiple resources: the Annual Environmental Survey of Polluting Firms, the Annual Survey of Industrial Firms, and county-level minimum wage policies by manual collection from 1999 to 2011. The estimation results indicate a positive and significant correlation between minimum wage policies and manufacturing firm's COD emission, just like the Chinese proverb "Good fortune has its roots in disaster, and disaster lurks with good fortune. Who knows why these things happen, or when this cycle will end?" by Lao Tzu, along with the labor protection, this policy instrument also brings about polluter production. Specifically, a one-standard-deviation raise in the minimum wage would trigger a 2.53% COD emission increase relative to average emission. Our results remain robust to alternative samples, measurements of minimum wage and pollution, and clustering levels, and this environmental effect is longstanding.

To further sharpen our empirical strategy and ensure the robustness of our findings, we switch identification strategy to that of Mayneris et al. (2018), Geng et al. (2022), and Kong et al. (2021). Specifically, we apply the difference-in-differences strategy based on 2004 minimum wage reform following Mayneris et al. (2018), refining firms into exposed and non-exposed groups to precisely examine the environmental impact of minimum wage policies. Then, following the strategy of Geng et al. (2022) and Kong et al., (2021) to address the potential spatial correlation problem, we only keep contiguous county pairs straddling two cities across the same borders while belonging to the same province and still find the significantly positive relationship between minimum wage policies and firm's COD emission. Moreover, to further alleviate the endogeneity problem, we also choose an instrument variable and our results remain unchanged. Together, our finding holds up for a battery of specifications: fixed-effect specification, difference-in-differences strategy, county pair model, as well as instrument variable estimation.

We further investigate the channels through which minimum wage triggers the intended environmental consequence. The direct mechanism is simply the pressures of labor cost and triggers the “factor substitution channel”, which implies a higher cost of doing business in China (Gan et al., 2016). Higher cost of labor always leads firms to choose equipment according to the factor substitution theory of Hicks (1932). Besides, firms may be uncapable to change their factor structure in the short term, thus have to face the heavier cost, which we conclude into “financial constraint channel”. Specifically, we firstly investigate firm’s labor input, capital density, energy consumption and COD yield, and demonstrate the trend to factor substitution which leads firms to consume more energy, thus generate more pollutants. Second, we investigate firm’s financial constraint and innovation level and find the higher labor cost can squeeze out the firm’s financial strength and innovation capacity. Finally, we find despite the fact that firms generate more pollutants, they haven’t significantly promoted their removal capacity, including firm’s investment in pollution abatement and removal capability. Additionally, this unintended environmental consequence is more significant in non-SOEs, labor-intensive industries, and regions with strong labor protection.

China is a meaningful case to analyze for a number of reasons. First, it is a typical showcase for the low-wage and minimum wage policies with wide earning inequality. And China officially launched its minimum wage system in 1993, and introduced “Regulations on Minimum Wage” in 2004. Moreover, comparing with establishing a single national rate in most European countries, China establishes a complex minimum wage systems with more than 50 rates (e.g., Heilongjiang province had 7 rates and Jiangxi had province 5 in 2011). And each region also dynamically adjusts their minimum wage standards regularly considering the regional economic development level, average wage level, consumption level and other factors. These exogenous changes of labor costs in time and space provide us an opportunity to further define exogenous effect of the cost of production factors and firm’s factor structure on firm’s environmental behaviors. Second, following the “grow first, clean up later” growth path, China is the largest polluter especially greenhouse gas emissions. Recently, China has emphasized more and more on environmental protection and introduces a series of environmental policies, for instance, stringent environmental regulations in five-year plan and National Specially Monitored Firms program (Zhang et al., 2018; Fan et al., 2019; He et al., 2020) and to achieve greener production, the policy interactions like green financing (Fan et al., 2021) is important. In sum, China is a key player in the global labor inequality and climate change challenge, thus we choose to explore the effect of cost of production factor on firm’s pollution emission in the context of China.

This study contributes to the literature in several ways. First, we complement the literature on the consequences of the minimum wage policy, and highlight the unintended environmental effects. Although extensive literature investigates the direct employment effect (for instance, Card and Krueger, 1994; Dube et al., 2010, 2016; Sturn, 2018; Neumark and Corella, 2021), and a growing body of literature further links minimum wage with firm's economic behaviors including firm's production, profitability, and export behavior (for example, Gan et al., 2016; Cuong, 2017; Mayneris et al., 2018).While to the best of our knowledge, the environmental effect of minimum wage policy remains undiscovered. By combining county-level minimum wage standards, firm-level financial indicators, and emission performances, we highlight the side effect of this labor protection policy, minimum wage triggers a significant increase in industrial firms' COD emissions.

Second, our study reveals the factors behind firms' environmental performance, i.e., cost and structural change, which is an extension of earlier studies on the relationship between the factor structure of production and environmental performance. Existing literature reveal factors affecting the firm's environmental performance mainly focus on technical factors (such as technological progress and green innovation), market factors (such as the carbon market, market competition, and trade), and institutional factors (such as environmental regulations and policies). Our research not only explains the reasons for changes in firm's environmental performance from the perspective of non-environmental policy, i.e., economic and social systems, but also reveals how will the changes in firm's factor structure and cost affect its environmental performance. And we outline the potential channel as "factor substitution channel" and "financial constraint channel".

Third, policy-makers could obtain several policy enlightenments from our results, especially enriching the understanding of policy interaction between labor and environment protection in developing countries. Since both labor and environment protection are main targets of the Chinese central government, numerous developing countries are in the path of "grow first, clean up later". On the one hand, the minimum wage is aimed to better protect labor's legal rights and interests; on the other hand, environment protection is also set as one of Chinese government's basic national policies since 1983, both policies matter a lot. Our study highlights the unintended environmental consequence behind the rising minimum wage policies could reminds policymakers of taking the interaction effect between policies into account, the adverse effect of labor and environment protection regulation faced by manufacturing firms in China, the largest developing country.

The remainder of this paper is structured as follows. Section 2 outlines the previous literature and section 3 introduces the minimum wage policy system in China. Section 4 sets out our empirical strategy which includes data, variable definitions, and model construction. Section 5 presents our findings, the unintended pollution effect of minimum wage, conducts a series of robustness tests including switching to abundant empirical models, and heterogeneity analysis. Section 6 discusses the potential channels. Lastly, Section 7 concludes.

2. Literature review

There is an extensive literature on minimum wage, firm abatement strategies and pollution emission behaviors, we briefly discuss these two streams of literature in this section.

2.1 Minimum wage

Since Card and Krueger (1994) introduced a quasi-natural experiment strategy to study the minimum wage issue, using New Jersey fast-food restaurants sample and shedding light on the surprisingly increased employment effect, the minimum wage has sparked a series of discussions (Card and Krueger, 1994; Dube et al., 2010, 2016; Allegretto et al., 2011; Giuliano, 2013; Huang et al., 2014; Neumark et al., 2014; Sturn, 2018; Cengiz et al., 2019; Bailey et al., 2021; Neumark and Corella, 2021). However, there is still no consensus on the employment effect. Giuliano (2013) supports the positive effect, and finds higher teenage labor market participation and higher absolute employment of teenagers, based on the 1996 federal minimum wage hike and U.S. retail firm data. Dube et al., (2010, 2016), Allegretto et al. (2011), and Sturn (2018) suppose the employment effect is only modest. While the negative effect is supported by Neumark et al. (2014) and Huang et al. (2014), they conduct empirical studies based on firm-level data in the U.S. and China respectively. Bailey et al. (2021) examine the 1966 Fair Labor Standard Act in U.S. and find a reduced aggregate effect. Neumark and Corella (2021) focus on developing countries and find the employment effects of minimum wages there are more likely to be negative.

In addition, a growing body of literature also investigates the relationship between minimum wage and firm's economic behaviors. Such as firm's production and business activities, productivity, profitability, fixed and human capital investment, innovation, export behavior, outward FDI, and survival probability (Gan et al., 2016; Long and Yang, 2016; Cuong, 2017; Cui et al., 2018; Mayneris et al., 2018; Kong et al., 2021). Among these, Long and Yang (2016) find private firms in China cut worker's benefits such as pension and insurance, and lay off low-skilled and short-term workers in response to the rising minimum wage. Chen (2019) finds manufacturing firms increase capital investments like machine in the U.S. due to minimum wage. Cui et al. (2018) suppose rising minimum wage leads to lower bank credit and higher loan default rates, which triggers the precautionary motivation for labor-intensive firms to save cash in order to reduce operating leverage and financial distress. And the relationship between minimum wage and firm's innovation is still confounding. However, the relationship between minimum wage and firm's environmental performance has been overlooked, we complement this research gap by focusing on the consequences of the minimum wage policies from the environmental perspective, which is beneficial to develop a comprehensive understanding of the effects of minimum wage.

2.2 Firm's emission behaviors

A substantial number of studies on the environmental economics have investigated the determinants of firm's pollution emission behavior and found that environmental regulation (Chen et al., 2018; Fan et al., 2019), financial policy (Fan et al., 2021), and individual characteristics, such as firm's human capital investment (Chen et al., 2021), abatement expenditure and technology choice (Gutiérrez and Teshima, 2018), credit constraint (Andersen, 2017; Sun et al., 2019; Zhang et al., 2020) are part of the determinants, covering from the macro-level policy orientation and minor-level firm's characteristics. However, most studies focus on environmental and financial policy's effect on firm's environmental performance, and few studies examine the environmental effect of minimum wage policy which directly impact on labor factor cost. The most related study investigates environmental changes by labor policy, mainly focusing on labor transfer, for example, Shao et al. (2021) find rural labor transfer increases the livelihood of communities exposed to rural industrial pollution in China. We complement this research gap by investigating the environmental effect of minimum wage, which is a prevalent labor protection policy around the world.

3. Minimum wage system in China

China firstly issues its national minimum wage regulations in 1993, and the 1994 *Labor Law of the People's Republic of China* firstly imposed obligations in terms of labor wages from the legislative level (Geng et al., 2022). It's worth noting that China didn't set a unified minimum wage policies in the entire country like many developed countries and chose to put the task of setting and adjusting regional policies on the shoulders of local governments (Kong et al., 2021). Specifically, the minimum wage is decided by provincial governments, who can negotiate with local governments at the city and county levels to choose the best standard. As a result, counties belonging to the same city may have various minimum wage rules. In 2004, the Ministry of Labor and Social Security of China further published the *Provisions on Minimum Wages* (hereafter referred as Provision), which officially empowers the departments of labor and social security of the people's governments at or above the county level shall be responsible for the supervision and inspection. And Provision also publishes five principles for choosing the appropriate standard, which include: (i) the lowest living expenses of workers and the average number of dependents they support; (ii) local average wages; (iii) labor productivity; (iv) local employment; (v) levels of economic development across regions. Additionally, the Provision also emphasizes local governments should adjust their standards at least once every two years, cover more workers including formal and informal workers, introduce an hourly minimum wage standards for part-time workers, shorten the adjustment cycle and enlarge the coverage. Thus, not only minimum wage has not only cross-section variance, but also cross-period variance (Geng et al., 2022). The supervision of firm compliance with labor regulations was also further tightened in 2004 following the promulgation of the Decree on Labor Inspection by the State Council (Mayries et al., 2018). Together, the significant cross-county and cross-period variances in the minimum wage policies in China allow us to discover the relationship between local minimum wage policies and firms' pollution emission behaviors.

In China, average minimum wage standards were below 400 Yuan (62 US dollars) in 1999 while ranged between 550 and 1300 Yuan (between 86 and 205 US dollars) in 2011. Fig. 1 plots the average minimum wage across counties in our sample from 1999 to 2011, which can further present the overall minimum wage increasing trend.

[Fig. 1. here]

Not only the changes in time, there also exist huge differences across regions the same province or even the same city. In 2011, the nationwide standard deviation of the minimum wage was 153 Yuan, excluding the municipalities, the highest minimum wage was in counties in Hangzhou city, Zhejiang province at 1310 Yuan, and the lowest was in Liuzhou city, Guangxi province at 565 Yuan per month, which account only 43% in Hangzhou. Within the same province, for example, in 2011, it ranged between 680 and 1010 Yuan in Anhui province, while it ranged between 850 and 1300 Yuan in Guangdong province. Overall, the exogenous changes in time and space of county's minimum wage policy provide us the opportunity to refine the identification of the relationship between the cost of production factor and firm's pollution behaviors.

[Fig. 2. here]

4. Empirical strategy

This section introduces data sources and variable definitions employed in our firm-county-year panel, and also shows our baseline empirical strategy to capture the environmental impact of minimum wage policies.

4.1 Data and variables

In our analysis, we combine data from 4 datasets, including minimum wage (MW) at the county level, firm-level financial data from the Annual Survey of Manufacturing Firms, firm-level pollution data comes from the Annual Environmental Survey of Polluting Firms of China, and the county-level socio-economic variables from CEIC database.

(1) Since there is no uniform data source for the minimum wage policies enacted by the county government between 1999 and 2011, we manually collect the minimum wage standards by browsing province, city, and county government websites, statistics bulletins, and online searches of local labor and civil reports. And we finally obtain the minimum wages for 1487 counties among most provinces in China. Following Fan et al. (2021), we use the log value of monthly minimum wage at the county-year level to empirical study (labeled as *lnMW*).

(2) Firm-level pollution data is from the database of Environmental Statistics, which is the Annual Environmental Survey of Polluting Firms (AESPF) in China, which covers heavily polluting firms that account for 85% of the regional (county-level) emissions of major pollutants. These polluting firms must submit their quarterly and annual pollution emission information, including emissions of major pollutants and pollution abatement technology, to the Ministry of Ecology and Environment, which is formerly known as the Ministry of Environmental Protection, or MEP (He and Zhang, 2018; Fan et al., 2019). Among these pollutants, COD is commonly used to reflect the water quality by measuring the amount of oxygen that can be consumed by reactions. Although each five-year plan in China has a different list of significant pollutants, COD is always included, that is, within the time period of our sample, the central government always attaches importance to COD. Specifically, the 9^{th} five-year plan (1996–2000) had 12 "important pollutants", the 10^{th} five-year plan (1991–2005) had 6, and the 11^{th} five-year plan (2006–2011) narrowed into 2, and COD is always on the list. Therefore, we conduct our investigation on firm's pollution by focusing on the continually critical pollutant in China, firm's COD emission, as a proxy variable for its environmental behaviors (labeled as *lnCOD*).

(3) Firm-level financial data is from the annual survey of manufacturing firms (ASIF), which

is collected by the central government through the Industry Statistical Reporting System. This dataset has been widely used in previous research on the Chinese economy (e.g., Gan et al., 2016; Brander et al., 2017), since it contains detailed information on Chinese firms, including basic information. Through registered address we can combine firm-level variables and county-level minimum wage policies, and full-scale accounting statements (Fan et al., 2019). While it still contains missing or abnormal values, therefore, we filter the data in accordance with the body of literature (Geng et al., 2022; Kong et al., 2021). Specifically, we remove samples that clearly violate accounting policies, such as those whose fixed assets exceed total assets, industrial value added, gross industrial output, paid-in capital, fixed assets, or inventories are zero or negative, and we only keep manufacturing firms.

(4) County-level socioeconomic variables are extracted from the China Statistical Yearbook (county-level). To address the concerns of omitted variable bias, we control variables including log population and log GDP per capita, in our empirical specifications. And we also include per capita gross domestic product (GDP), the percentage of GDP from secondary industry, and the ratio of general fiscal budget expenditure to GDP.

[Table 1. here]

Specifically, to get our firm-county-year level panel dataset, we first merge the ASIF and AESPF based on firm's name and registration number. Then based on the firm's location information, we merge the firm-level dataset including financial and environmental variables with county-level minimum wage policies. Our cleaned dataset spans from 1999 to 2011, and contains data on 38850 firms from 1487 counties, finally includes 133,750 firm-county-year observations. In order to eliminate macroeconomic trends and inflationary effects, exclude the outliers and eliminate macroeconomic trends and inflationary effects, we deflate economic variables based on the year 1999 and winsorize continuous variables at 1% to 99%. Table 2 reports summary statistics of the key variables employed in our study, the mean value of *lnCOD* in our sample is 5.98 with a standard deviation of 4.38, which further illustrates the stark disparity in the firm's pollution levels across various industries and areas.

[Table 2. here]

4.2 Model

We construct the following specification for our empirical investigation:

$$lnCOD_{ict} = \alpha_0 + \alpha_1 lnMW_{ct} + \alpha_2 X_{it} + \alpha_3 Z_{ct} + \sigma_i + \epsilon_h + \mu_c + \delta_t + \varepsilon_{ihct} \quad (1)$$

where $lnCOD_{ict}$ indicates the log value of COD emissions of firm i in year t, and $lnMW_{ct}$ indicates the log value of the monthly minimum wage in county c and year t. In Eq. (1), X_{it} is a vector of firm-level characteristics, and Z_{ct} is a vector of county-level characteristics. Specifically, the vector X_{it} includes log total assets, leverage defined as total debt scaled by total assets, inventory defined as inventory scaled by total assets, capital defined as fixed assets scaled by the total assets, and ROA defined as profits scaled by the total assets. The vector Z_{ct} includes log GDP, log GDP per capita, log population, the percentage of GDP from secondary industry, and the ratio of general fiscal budget expenditure to GDP. And we specify the error term to have σ_i, μ_c, ϵ_h and δ_t representing the firm, county, industry, and year fixed effects, and a white noise error ε_{ihct}. The σ_i accounts for unobserved time-invariant differences across firms that may influence a firm's decisions and behaviors on pollution emission. That is, we want to focus on the within-firm variation arising from the changes in the minimum wage faced by firms. Besides, we use ϵ_h industry fixed effects and μ_c county fixed effects to capture the unobserved time-invariant differences across industries and counties, and δ_t time-variant differences between years.

The parameter of our interest is α_1, which measures the effect of minimum wage on firm's pollution emission behavior. We cluster standard errors at the county level considering the potential serial correlation, following Fan et al. (2018), and Mayneris et al. (2018).

5. Empirical results and analysis

In this section, we provide direct evidences of the side effect of minimum wage policy—— heavier firm pollution emissions, and we next conduct a series of analyses to verify the robustness of our baseline findings.

5.1 Baseline results

Table 3 presents the estimation results of Eq. (1). In column (1), besides the variable $lnMW$, we include only firm fixed effects and year fixed effects. Then, considering different industries emit pollution at different rates, for instance, the top 6 industries in terms of COD emissions in China in 2006 account for 76.08% of China's total COD emissions.[1] Besides, the variation of

[1] Specifically, the top 6 industries emitting COD in China in 2006 are: papermaking and paper products, agricultural and sideline foods processing, manufacture of raw chemical materials and chemical products, textiles, mining and processing of ferrous metal ores and manufacture of wine, and drinks and refined tea, according to *China Environmental Statistics Annual*

minimum wage policies in our study is county-level. Thus, we further include the industry fixed effects according to 4-digit manufacturing industry code, and include county fixed effects in column (2). Next, we control firm-level control variables in columns (3) and (4), and further add county-level socioeconomic control variables in columns (5) and (6). While columns (4) and (6) contain industry fixed effects and county fixed effects. And in column (7), we further include the industry-year fixed effects to capture the time-varying differences across industries.

From columns (1) to (7), both the coefficients of *lnMW* and standard errors are barely changed, and we take column (6) as our preferred baseline results. To gauge the importance of minimum wage increases for firm-level pollution emission in China, we conduct a simple back-of-the-envelope calculation. Based on our preferred estimate in column (6), 0.5320, and the average monthly minimum wage increases by 1.29 log points (from 243.5 yuan to 884.5 yuan) in our sample, our specification predicts an increase in firm-level COD emission by 0.6862 log points, which would adverse to promote the implementation of China's energy-saving and emission reduction policies. And more intuitively, the estimated coefficient on log minimum wage is 0.5320, and statistically significant at the 5% level. This implies that a one-standard-deviation raise in minimum wage will lead to a 2.5261% COD emission increase relative to average emission.[2]

[Table 3. here]

In sum, we find the rising minimum wage of a county is associated with non-negligible side effect——severer firm's COD emissions. The finding holds up well when several firm-level control variables and county-level control variables are taken into account.

5.2 Robustness analysis

In this subsection, we conduct a series of tests to check the robustness of our baseline findings, including alternative samples and measurements, alternative standard error clustering level, the potential medium-run effect, and a placebo test.

5.2.1 Alternative samples and measurements

According to Kong et al. (2021), we **first** exclude the counties belonging to capital cities

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Report-2006 by MEP.

[2] The standard deviation of *lnMW* is 0.2837, the coefficient of *lnMW* is 0.5320 in column (6) containing all control variables, firm fixed effects, year fixed effects, county fixed effects, and industry fixed effects, and the mean value of *lnCOD* is 5.9747. Thus, 0.5320*0.2837/5.9747=2.5261%.

which may have superior rights compared to others in numerous aspects, in our case, it means firms in counties belonging to capital cities may enjoy financial convenience than others, or take more environmental responsibility than others, which may bias our conclusion. **Second**, following Dube et al. (2010), we exclude the counties with an area of more than 2000 square miles since they are less likely to share common characteristics with others. **Third,** considering the sample period is from 1999 to 2011 and in order to exclude the confounding impact of China's World Trade Organization (WTO) entrance in 2001, we exclude the period before accession to let the subsample be comparable. As noted by Branstetter and Lardy (2008), China's final accession in November 2001 brings about increased economic openness and institutional improvements. These changes also push firms to technical improvement and can affect environmental behaviors, thus may bias our findings. **Fourth**, considering counties with higher average wages means firms there may be less impacted by the minimum wage reform, and to address the heterogeneous effects of the minimum wage across counties with various average wages, we **use the difference between the minimum wage and that baseline average wage in 2006** as the new independent variable following Kong et al. (2021). **Fifth**, we re-estimate the relationship between minimum wage and other pollutants. Besides COD, SO2 is also a pollutant remaining unchanged in China's five-year plans, thus we investigate the relationship of minimum wage and SO2. Our re-estimate results are shown in Table 4 respectively. Columns (1)-(5) present that the coefficients on *lnMW* remain significantly positive, which reveals the polluter effect of minimum wage is robust.

[Table 4. here]

5.2.2 Alterative standard errors clustering levels

When it comes to the minimum wage system in China, the central government directly appoints officials at the province level rather than the municipal and county level, and the subordinate governments are more directly responsible at the province governments. Besides, county governments belonging to different city and province administrations may face different requirements as well. Therefore, in order to further exclude the influence of city-level and province-level factors, we re-estimate the regression by changing the cluster level to the city and province level. The results are shown in columns (1) and (2) of Table 5, which remain significantly positive and partially relieves our concern.

5.2.3 The potential medium-run effect

So far, our study has only focused on the current environmental effect of the rising minimum wage. While those productivity factor adjustments need time to prepare for and achieve, regardless of the labor force or equipment (Mayneris et al., 2018). Thus, we further consider the lagging medium-run effect, specifically, we re-estimate our baseline model by replacing the dependent variable by its values at year *t+1* and *t+2* successively, instead of at year *t*. The regression results are shown in columns (3) and (4) of Table 5, and we could observe the coefficients remain significantly positive. Compared with our baseline coefficient α_1, 0.5320, the coefficient on $lnCOD_{t+1}$, 0.7277, and coefficient on $lnCOD_{t+2}$, 1.1374 are larger in magnitude, which means medium-run side effects of minimum wage on the environment (both 1-year lag and 2-year lag) are even stronger, which needs more attention to solve.

[Table 5. here]

5.2.4 Placebo test

To check the extent to which our baseline findings are influenced by omitted variables, we conduct a placebo test by randomly assigning county-level minimum wage policies to manufacturing firms (see Bradley et al., 2017). That is, we randomly assign false county-level minimum wage to each firm and re-estimate the relationship between the minimum wage policies and firm's COD emission based on the fake sample. Ans to increase the identification power of this placebo test, the fake estimation is repeated 500 times. Fig. 2 shows the distribution of the t-value from the 500 runs along with our baseline estimators, 2.37. The distribution of the t-value from random assignments is clearly centered around zero, suggesting that there is no effect with the randomly constructed minimum wage reform. Meanwhile, the baseline t-value is almost located outside the distribution. Combined, the placebo test further suggests that the unintended environmental consequence of the minimum wage is not driven by unobserved factors.

[Fig. 3. here]

5.3 Endogeneity analysis

To further remedy the endogeneity problem between macro-level minimum wage policies and micro-level firm's environmental behaviors, we now turn to conduct a series of endogeneity tests including taking advantage of 2004 *Provision* reform shock, altering our specification, and conducting an instrument variable test.

5.3.1 The 2004 minimum-wage reform

Considering our sample period covers from 1999 to 2011, China introduced the new minimum wage regulations, *Provisions on Minimum Wages*, Order of the Ministry of Labor and

Social Security of the People's Republic of China (No. 21) in 2004, a mandatory standard further imposes higher minimum wage standards and stricter enforcement. This reform can be seen as an exogenous shock and gives us the opportunity to conduct a quasi-natural experiment. Now we turn to exploit the environmental effect of minimum wage by difference-in-differences estimation. Mayneris et al. (2018) provide a strategy to identify the effect of this reform, based on the frameworks of Harrison and Scorse (2010) and Draca et al. (2011). By comparing the average wage of the firms (total wage bill over employment) in year *t-1* and the local minimum wage policies in year *t*, we separate firms into exposed and non-exposed groups. The exposed is the treatment group, and the non-exposed is the control group. And we construct the following model:

$$lnCOD_{it} = \beta_0 + \beta_1 exposed_{it} + \beta_2 exposed_{it} \times reform_t + \beta_3 Z_{ct} + \sigma_i + \epsilon_h + \delta_t + \varepsilon_{ihct} \quad (2)$$

where $lnCOD_{it}$ indicates the log value of COD emissions of firm i in year t, $exposed_{it}$ is a dummy for the firm's average wage at *t-1* being below the local minimum wage at t, $reform_t$ denotes the post-reform period, taking a value of 1 for 2004 and later years and 0 otherwise. Other variables are consistent with Eq. (1). Our key variable of interest is the interaction between the firm exposed dummy and post-reform dummy, and our coefficient of interest is β_2, measuring the gap in COD emission between exposed and non-exposed firms in the post-reform period, relative to the exposed and non-exposed firms in the pre-reform period, which reflects the environmental effect of minimum wage policy and it will support our baseline finding if β_2 is positive.

The column (1) in Table 6 presents the results of Eq. (2) estimation. All else being equal, we conduct a back-of-the-envelope calculation that the average COD emission gap between exposed and non-exposed firms increased by 17.4% ($e^{\wedge 0.1605}$-1) after the 2004 reform compared to its pre-reform. The result is in line with our baseline finding, firms exposed to the minimum wage would pay less attention to their environmental performance, which leads to the unintended side effect, heavier COD emission result accompanying this stronger labor protection. Besides, still following Mayneris et al. (2018), we further construct a model to investigate the change before and after the 2004 minimum wage reform on COD emission pollution as follow.

$$LnCOD_{it} = \beta_0 + \beta_1 lnMW_{ct} \times pre04 + \beta_2 lnMW_{ct} \times post04 + \beta_3 Z_{ct} + \sigma_i + \epsilon_h + \delta_t + \varepsilon_{ihct} \ (3)$$

The results of our re-estimation of the alternative model (3) are displayed in column (2) in Table 6. It implies that introducing **2004 *Provisions*** leads to a significant increase in the effect of the minimum wage on COD emission behavior. Not only the coefficient is larger in magnitude, but also the significance improved from 10% to 5% after 2004, the results once again confirm the side effect of minimum wage increase in firm-level COD emission.

[Table 6. here]

5.3.2 Pairs of contiguous counties

In order to remedy the two main weaknesses of traditional fixed-effect specification: omitted unobservable variables and spatial autocorrelation. Taking advantage of minimum wage policies differences between pairs of contiguous counties, Dude et al. (2010) firstly carried out a local identification strategy in the context of the U.S., then Geng et al. (2022) and Kong et al. (2021) follow this strategy and apply it in China. Although we control a series of fixed effects including county fixed effect in baseline strategy, we still worry about the unobserved omitted variable problem, thus we now adopt the specification of Dude et al. (2010) to focus on firms in the contiguous counties. That is, counties belong to the same province, while straddling two cities and across the same borders, in order to ensure similarity in local's economic and firm characteristics. Specifically, we construct the following model:

$$lnCOD_{it} = \alpha_0 + \alpha_1 lnMW_{ct} + \alpha_2 X_{it} + \alpha_3 Z_{ct} + \sigma_i + \tau_p + \epsilon_h + \delta_t + \varepsilon_{ihcpt} \quad (4)$$

where τ_p is the county-pair fixed effect to capture spatial heterogeneities that exist around the shared border of two contiguous counties, instead of μ_c in Eq. (1) which refers to the county fixed effect. We exclude firm samples in counties across the provincial borders which couldn't ensure the similarities based on the potential regulatory pattern differences, thus may bias the estimated casual identification (Geng et al., 2022), and counties belonging to the same cities since the high possibility to change the minimum wage policies simultaneously (Kong et al., 2021). Finally, we identify 2413 county pairs and 1109 border counties. We include the county-pair fixed effects in column (1) in Table 7, the coefficient of *lnMW* remains positive and similar in magnitude, and still statistically significant at 10% in county pair sample, which partially relieves our concern.

5.3.3 IV and 2SLS

We further conduct an instrumental variable (IV) estimation and a two-stage least squares regression (2SLS) to relieve our concern about the potential reverse causality. According to the IV strategy of Fisman and Svensson (2007), considering the relevance and exogeneity conditions, we choose the average minimum wage policies of other counties within the same province as instrumental variable. The reasons are as follows. First, economic and social factors like geographic location, factor endowment, history, and culture are relatively similar within the same province, and the minimum wage policies set by county government subordinated to same province has highly correlation. Second, county-level governments in the same province would take less account of the firm's environmental behavior in other county, when setting minimum wage policies. Since firms located in other counties have less impact on its goal, thus the exogeneity hypothesis is satisfied. In Table 7, the column (2) shows this instrument is a good predictor of *lnMW*, and it passes the weak instrument test as indicated by a Kleibergen-Papp Wald rank F-statistic much larger than 10. The column (3) presents the coefficient of the instrumented *lnMW* remains significantly positive, with huge change in magnitude.

[Table 7. here]

5.4 Heterogeneity analysis

In this section, we identify whether all firm's emission behavior is equally affected by the rising minimum wage policies in three dimensions. First, we explore the heterogeneity according to firm's ownership. Second, we expect minimum wage policies will induce stronger environmental consequence on labor-intensive industries since they will face with heavier labor costs. Third, considering the workforce protection environment varies across China, we suppose different protection regions will witness different effects.

5.4.1 Firm's ownership type

First, state-owned-enterprises (SOEs) are usually more likely to receive support from the government and obey national multi-objectives. On the one hand, there are fewer barriers to raising funds for SOEs due to their monopoly advantages since the historical dual-track system with a planned economy and implicit government guarantees, whereas non-SOEs face more stringent financial restrictions and higher financing costs than SOEs (Song et al., 2011). Considering SOEs are more likely to receive government's subsidies and support when facing with rising labor costs, we suppose the burden of SOEs due to the minimum wage is less severe than non-SOEs. On the other hand, SOEs take on additional political and social responsibility and adhere to national policy directives, rather than non-SOEs' unitary goal of maximizing profit. Given that China has been leading environmental revolution in energy efficiency and emission reduction since 2006, we suppose SOEs will exert greater effort to reduce emissions than non-SOEs. Together, not only from the perspective of financial constraint and firm's political responsibility, we suppose the unintended consequence of minimum wage would be less severe in SOEs.

We classify our sample according to their ownership: SOEs and non-SOEs to examine the effects of minimum wage on firms by ownership. Columns (1) and (2) of Table 8 show that the relationship between *lnMW* and firm's COD emission significantly differs between SOEs and non-

SOEs, the former is insignificant negative, while the latter is 0.6254, statistically significant at 1% level. Thus, non-SOEs is more responsive to this unintended side effect of minimum wage policy, protecting low-wage labors while at a cost of environment.

5.4.2 Industry's labor intensity

Third, we examine whether industries with different degrees of relying on labor for production react differently, where labor-intensive industry means industries heavily reply on labor factor (Kong et al., 2021). We suppose the same increase of minimum wage will induce a stronger effect on the marginal cost for higher labor-intensity industries, and further squeeze out the money for cleaning production and pollution abatement requirements. Thus, we divide the sample into higher and lower labor-intensive subsamples according to the two-digit industry code and re-estimate the regression respectively.[3]

As shown in columns (3) and (4) of Table 8, the coefficient on log minimum wage is positive and statistically significant for higher labor-intensive industries while insignificant for the less labor-intensive industries, which in line with our conjecture. That is, labor-intensive industries are relatively more affected by the minimum wage policy comparing to the capital-intensive industries, thus the higher labor cost burden

5.4.3 Regional labor protection environment

Last, we consider the policy-enforcing degrees of minimum wage varies across China, which is closely related to local workforce protection environment. Referring to the National Economic Research Institute Index of Marketization of China's Provinces, which assesses the marketization progress in five aspects: (1) the relationship between government and market, development of the non-state industry, (2) development of product markets, (3) development of factor markets, and (4) the development of market intermediaries, as well as (5) the market-friendly legal environment. We choose the provincial third-level indicator (B5): "Protection of the legal rights and interests of producers" to proxy for regional labor protection atmosphere, and divide our sample into two groups: strong and weak labor protection, and rerun our regression.

As shown in columns (5) and (6) of Table 8, the rising minimum wage policies significantly

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[3] Specifically, higher labor-intensive industries include 14 manufacturing industries: agricultural and sideline foods processing; food production; textile industry; clothes, shoes and hat manufacture; leather, furs, down and related products; timber processing; bamboo, cane, palm fiber and straw products; furniture manufacturing; papermaking and paper products; printing and record medium reproduction; cultural, educational and sports articles production; rubber products; plastic products; nonmental mineral products and metal products.

increase the firm-level COD emission in strong protection regions, while insignificant in weak regions. These different results prove that protecting workforce's legal right which strengthens the implementation of minimum wage policies, would further squeeze the capability for firms to apply the abatement and environmental behaviors, thus heavier pollution side effect in strong protection regions. Besides, these results further confirm the pollution consequence truly comes from the higher labor cost.

[Table 8. here]

6. Potential channels

Why does this unexpected environmental damage occur? A natural and interesting question here is why a labor-friendly atmosphere significantly care less about environment which is still closely connected to people's health. What kind of firm's behavior shifts happen when firms are facing with more stringent labor protection regulations? It becomes necessary to investigate firm's behavior transformation behinds, the main stream divide the impact of rising labor cost into "factor substitution effect" and "cost effect", we follow this logic and restate channels in "factor substitution channel" and "financial constraint channel" in our analysis, where "financial constraint channel" further include two sub-channels including innovation and investment.

6.1 Factor substitution channel

The "factor substitution" theory was developed as a result of Hicks (1932) assertion that "A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind——directed to economizing the use of a factor which has become relatively expensive." Previous studies support it theoretically and empirically that firms tend to fire workers and replace them with equipment and capital to protect profits and accomplish profit maximization goals (Klasa et al., 2009; Matsa, 2010; Giuliano, 2013; Mayneris et al., 2018; Chen et al., 2019; Harasztosi and Lindner, 2019). Since the formerly unprofitable machinery and equipment are now becoming profitable due to the rise of labor costs, it will change firm's production and operation decisions, that is, firm's factor substitution behaviors can induce a non-negligible impact on firm's factor structure, the level of fixed asset investment, capital stock, etc. (Stigler, 1946; Flinn, 2006; Giuliano, 2013). And we suppose this factor restructuring will lead firms to discharge more pollutants, since firms tend to choose equipment rather than workforce, which requires energy inputs for production and generates more wastewater and waste gas. This change will cause unforeseen environmental consequences and go against China's abatement goal.

Based on the above analysis, we first investigate the impact of local minimum wage policies on firms' labor scale (the average annual number of employees), and capital intensity (the ratio of the firm's fixed assets to a number of employees). Second, following Chen et al. (2020), we calculate firm's usage of energy consumption scale from AESPF dataset by converting coal, oil and natural gas to standard coal, so as to investigate whether minimum wage policies indeed lead firms to consume more energy in production. Third, we use COD yield indicating the firm's annual yields of COD in the production process but before the pollution abatement process (Zhang et al., 2018), to explore whether the firm's factor substitution change results in generating more COD. Columns (1) and (2) in Table 9 present our estimated effect of minimum wage policies on firm's labor scale, and capital intensity, the results indicate minimum wage indeed triggers significant factor substitution behaviors, consistent with the previous findings. The results of columns (3) and (4) present the impact of minimum wage on firm's energy consumption and COD yield, the significantly positive effect confirms our conjecture that this firm restructuring indeed leads to more energy consumption and dirtier production.

[Table 9. here]

6.2 Financial constraint channel

Although "factor substitution channel" highlights minimum wage policy leads firms to choose machinery in order to avoid higher labor cost, while not all firms exposed to minimum wage policies are able to immediately adjust factor structure or pass on the increased costs to customers. Cash flow can limit firm's ability to produce and operate (Hall, 2002), when firms have to take on higher labor cost, they would simultaneously suffer cash shortage and heavier financial distress (Gan et al., 2016; Cui et al., 2018). Besides, there are primarily two methods to achieve greener businesses: cleaner production (CP) adjustments, which refers to firms improve their production technology or equipment to achieve cleaner production and produce less pollutant yield, and end-of-pipe (EOP) interventions, which refers to firms remove more pollutants (Fan et al., 2019; He et al., 2020). In sum, we suppose financial constraint is another channel that influences industrial firms' emission behaviors in China. On the one hand, tighter financial constraint could limit firm's innovation behaviors, making it harder to achieve CP adjustments; on the other hand, firms are less able to afford abatement facilities, making it harder to achieve EOP interventions.

6.2.1 Limit innovation

Financial constraints may jeopardize a firm's research and development (R&D) in order to earn short-term operating profits (Dang et al., 2022), yet firm's self-innovation is critical in CP transformation to attain greener output. Besides, in the contemporary China, the largest developing country who still struggles to improve its intellectual property protection environment, where firm's innovation results are more easily imitated and applied by other firms in the industry than in developed countries. This phenomenon reduces firm's innovation revenue and leads to a cost-benefit mismatch, thus ruins firm's innovation incentive (Brander et al., 2017; Zhao and Li, 2016), crowds out firm's ability to R&D investment and harms its innovation outcome (Klasa et al., 2009; Matsa, 2010). Besides, Bradley et al. (2017) highlight bottom-level workers are often the back-up support for R&D activities and have a significant impact on firm's R&D performance, which means firm's factor restructuring can harm its innovation from the practice experience accumulation mostly from rank-and-file employees, the targeted protection group of minimum wage policy. In sum, we suppose under the background of China's weak intellectual protection environment, rising labor costs leads firms to cut off grassroot workers and face tighter financial constraint will both limit firm's innovation inputs and output. However, given the data limitation, we use patents to measure firm's innovation from the perspective of output rather than input. We hypothesize the rising minimum wage will harm a firm's ability to innovate, as well as its ability to make CP adjustments which reflects on its COD yield ratio (i.e., COD yield per unit of output).

Based on the above analysis, we first investigate the effect of local minimum wage policies on firms' financial constraint by calculating SA index, given that ASIF dataset doesn't disclosure detailed cash flow to calculate KZ index. And we take its opposite to positively stand for financial constraint to positive proxy for financial constraint. Column (1) of Table 10 shows that significant positive coefficient of minimum wage on financial constraint, indicating this strict labor protection policy tightens firm's financial constraint, which fits with our intuition. By combining the firm-level patent data from China's State Intellectual Property Office (SIPO) patent database with ASIF, (He et al., 2020) we obtain firm-level patent (including invention, utility, design, and total) information. And the regression results are shown in columns (2) - (5). We can observe a negative effect of minimum wage on firm's patents, extremely significant for invention patents. Considering Chinese invention patent is similar to U.S. utility patent, which aims to protect new technological solutions relating to products, including processes or improvements. Thus, it is the most production- and technology-related patents that demonstrated firm's innovation outcome, and the significantly negative coefficient of invention patent seems enough to reveal the harm. Column (6) presents our estimated effect of minimum wage on firm's COD yield ratio, the significantly positive estimator indicates that due to the financial constraint and innovation limit, firms are less capable to achieve greener CP adjustment.

[Table 10. here]

6.2.2 Restrain abatement investment

Above we discuss the impact of financial constraint on firm's CP adjustments, now we turn to explore the impact of minimum wage on firm's EOP interventions. Facing with heavier labor costs, we suppose firms are less capable to afford abatement facilities, while going greener must invest in environmental equipment (Qi et al., 2021). Specifically, we first use the number of new effluent treatment facilities in the current year to stand for firm's abatement investment, the long-time period of our dataset allows us to use first order difference to examine this channel. And we use firm's COD removal ratio calculated as COD removals divided by total output to stand for EOP performance. Since firm's COD emission can be decomposed into COD yield and COD removal, the latter indicates its annual removal of COD during EOP process (Zhang et al., 2018).

Columns (1) and (2) of Table 11 present both insignificant estimator of firm's abatement facility and COD remove ratio, which indicate industrial firms are less capable to purchase EOP facilities and improve their pollutant remove ability with the rise of minimum wage. Combining the results from columns (1) and (2), we can conclude that the rising labor cost leads to tighter financial constraint, which also make it difficult to achieve firm's EOP interventions and results in severer COD emission.

[Table 11. here]

7. Conclusions

The rising minimum wage in China over the past decades has sparked heated debates in both media and research. This study extends the research on minimum wage by shedding light on its unintended environmental consequence. We use an extensive firm-county-year panel dataset of medium and large manufacturing firms in China from 1999 to 2011 to analyze the relationship of county-level minimum wage standards and firms' emission behavior, and we find the significant increases in firms' COD emissions. We provide convincing and robust evidences through a series of robustness checks including a battery of specifications including DID experiment based on 2004 reform, county-pair model, as well as IV estimation.

We conclude the potential mechanisms behind as “factor substitution channel” and “financial constraint channel”. Specifically, minimum wage induces firm’s factor restructuring of applying more equipment thus increasing emission density (producing more COD per unit output), however, the tighter financial constraints due to higher labor cost simultaneously harms firm’s ability to innovation and invest in abatement equipment which is detrimental to both CP adjustments and EOP interventions. Besides, this environment-destructive side effect is stronger in SOEs, labor-intensive industries, and strong labor protection regions. In sum, just like the traditional Chinese proverb “*Disaster lurks within good fortune*”, minimum wage policy is originally designed to protect low-wage workers, but it induces unexpected firm’s polluter production in the meanwhile which still harms people’s health. Our finding highlights the policy interaction effect behind is non-negligible between labor and environmental protection, which is meaningful for policy-makers, especially in developing countries with severe environmental degradation.

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Figures and Tables

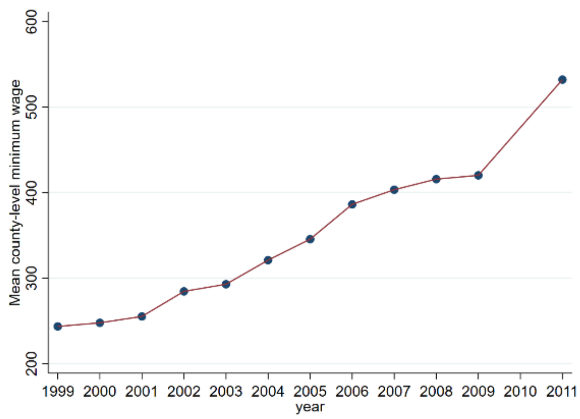
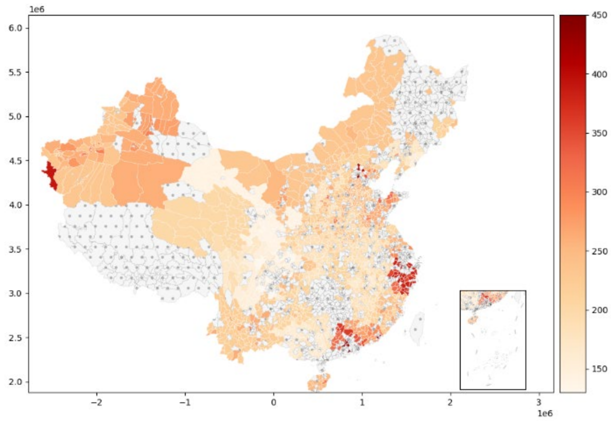


Fig. 1. Change in county-level minimum wage in China.

Notes: Fig. 1 plots the average annualized minimum wages across Chinese counties over the sample period from 1999 to 2011, which is in consistent with Geng et al. (2022).

Graph A. Year 1999



Graph B. Year 2011

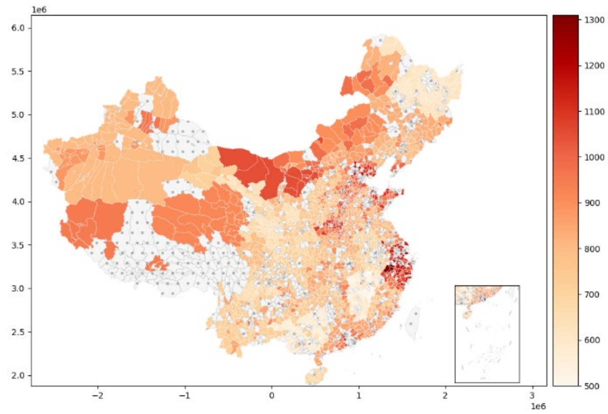


Fig. 2. Spatial distribution of county-level minimum wage in China.

Notes: Fig. 2 plots the in the years 1999 and 2011, the begin and end of our sample period. In each graph, counties are sorted by their minimum wage with the color, the darker is the area, the higher minimum wage local governments choose and set.

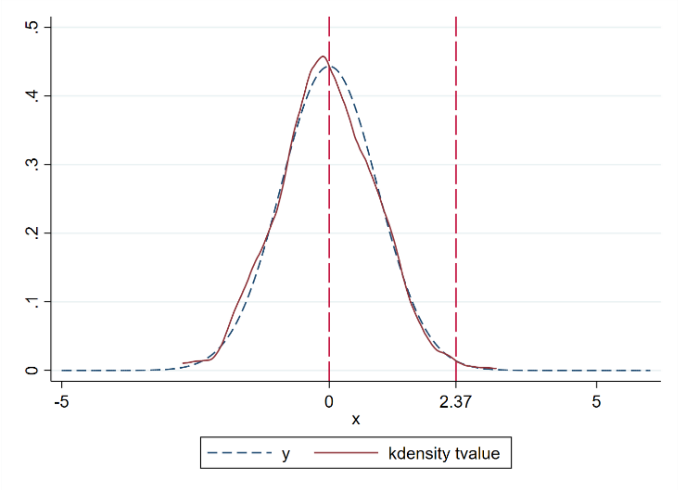


Fig. 3. T-value distribution of placebo test

Notes: the figure shows the cumulative distribution density of the t-value is from 500 simulations randomly assigning the county-level minimum wage to manufacturing firms. The solid red line represents the distribution of the t-statistics of 500 repeated random test t, the dash blue line represents the normal distribution, and the vertical red dotted line ($t = 2.37$) represents the t-statistics of our baseline regression (column (6) in Table 3).

Table 1

Variable Definition

Variable	Definition	Data Source
Firm-year variables		
lnCOD	Log value of firm's COD total emission (Kg)	AESPF
size	Log value of total assets (in thousand Yuan)	ASIF
lev	Total debt divided by total assets	ASIF
inven	Ratio of inventory over total assets	ASIF
capital	Ratio of capital over total assets	ASIF
roa	Return on total assets	ASIF
County-year variables		
lnMW	Log value of local monthly minimum wage (Yuan)	
lngdp	Log value of gross domestic product of county (in ten thousand Yuan)	CEIC
lnpgdp	Log value of per capita gross domestic product of county (Yuan)	CEIC
lnpopu	Log value of county's total population (in ten thousand) at the end of year	CEIC
stru	A county's% GDP from the second-industry	CEIC
gov	The ratio of general fiscal budget expenditure to GDP	CEIC

Table 2

Summary Statistics.

Panel A: Firm-year variables						
Variable	N	Mean	Std. Dev.	P10	Median	P90
lnCOD	133,750	5.9747	4.3848	0	7.1861	11.3426
size	133,750	10.2669	1.3208	8.5649	10.1312	12.2062
lev	133,750	0.6004	0.2597	0.2199	0.6144	0.9481
inven	133,750	0.1818	0.1371	0.0278	0.1497	0.4046
capital	133,750	0.4143	0.2037	0.1443	0.3995	0.7121
roa	133,750	0.0716	0.1299	-0.0347	0.0278	0.2335
Panel B: County-year variables						
Variable	N	Mean	Std. Dev.	p10	Median	p90
lnMW	14,327	5.8745	0.2837	5.4773	5.8827	6.2932
lngdp	14,327	13.2584	0.9758	11.8752	13.2672	14.6239
lnpgdp	14,327	9.2398	0.7235	8.2606	9.1983	10.2492
lnpopu	14,327	4.0450	0.5573	3.2189	4.0943	4.7604
stru	14,327	0.4700	0.1268	0.2846	0.476	0.6333
gov	14,327	0.1034	0.0598	0.0472	0.0834	0.191

Table 3

Baseline results.

Variable	*lnCOD*						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
lnMW	0.4987**	0.5519**	0.4672**	0.5292**	0.4687**	0.5320**	0.4719**
	(0.2306)	(0.2258)	(0.2294)	(0.2249)	(0.2294)	(0.2245)	(0.2097)
size			0.2650***	0.2451***	0.2638***	0.2440***	0.2198***
			(0.0333)	(0.0326)	(0.0332)	(0.0324)	(0.0312)
lev			0.0680	0.0780	0.0699	0.0797	0.0800
			(0.0763)	(0.0740)	(0.0754)	(0.0732)	(0.0696)
inven			0.1603	0.1573	0.1561	0.1530	0.1481
			(0.1145)	(0.1133)	(0.1146)	(0.1133)	(0.1113)
capital			0.0298	0.0150	0.0310	0.0160	-0.0054
			(0.0837)	(0.0826)	(0.0832)	(0.0823)	(0.0785)
roa			0.0297	0.0589	0.0464	0.0676	0.1324
			(0.1406)	(0.1360)	(0.1429)	(0.1383)	(0.1248)
lngdp					0.1333	0.1580	0.1253
					(0.4007)	(0.3893)	(0.3633)
stru					0.1082	0.0287	0.1399
					(0.3635)	(0.3620)	(0.3470)
lnpgdp					-0.3726	-0.3945	-0.5171
					(0.8352)	(0.9270)	(0.7178)
gov					-0.9780*	-0.6843	-0.4412
					(0.5371)	(0.4998)	(0.4866)
lnpopu					2.1199**	2.0839**	2.8738***
					(1.0499)	(1.0433)	(0.9954)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	No	Yes	No	Yes	No	Yes	Yes
Industry FE	No	Yes	No	Yes	No	Yes	Yes
Industry*Year FE	No	No	No	No	No	No	Yes
Constant	3.0452**	2.7325**	0.4248	0.2634	-0.5931	-0.4014	-0.0837
	(1.3547)	(1.3268)	(1.4212)	(1.3879)	(4.3476)	(4.4832)	(3.7308)

N	133785	133750	133785	133750	133785	133750	132771
Adj R2	0.7406	0.7405	0.7411	0.7409	0.7413	0.7410	0.7479

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 4

Robustness 1: alternative samples and measurements.

	(1)	(2)	(3)	(4)	(5)
	Excluding capital cities	Excluding grand counties	Exclude the accession to WTO	*ln△MW*	*lnSO2*
lnMW	0.4379*	0.5284**	0.5209**	1.8498**	0.3006*
	(0.2489)	(0.2266)	(0.2334)	(0.9218)	(0.1670)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Constant	0.2938	-0.6368	-1.1555	-17.8791*	3.0853
	(5.0515)	(4.5110)	(4.3092)	(10.1204)	(3.2179)
N	121117	132614	115661	123204	120139
Adjusted R2	0.7369	0.7413	0.7503	0.7387	0.7733

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 5

Robustness 2: standard errors clustered at different levels and the medium-run effect.

	(1) Cluster at city level	(2) Cluster at province level	(3) $lnCOD_{t+1}$	(4) $lnCOD_{t+2}$
lnMW	0.5320**	0.5320*	0.7277**	1.1374***
	(0.2543)	(0.2779)	(0.3442)	(0.3813)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Constant	-0.4014	-0.4014	6.4993	-0.5272
	(5.2694)	(6.0168)	(5.1236)	(6.0021)
N	133750	133750	76424	61099
Adjusted R2	0.7410	0.7410	0.7767	0.7590

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 6

Endogeneity analysis 1: The 2004 minimum-wage Reform and firm-level COD emission.

	LnCOD	
	(1)	(2)
Exposed Firm	-0.0762	
	(0.0469)	
Exposed Firm×Reform	0.1605**	
	(0.0657)	
lnMW×pre04		0.4645*
		(0.2737)
lnMW×post04		0.5539**
		(0.2419)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
County FE	Yes	Yes
Industry FE	Yes	Yes
Constant	-0.4849	-0.4042
	(4.9470)	(4.4791)
N	87446	133750
Adjusted R2	0.7338	0.7410

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 7

Endogeneity analysis 2: county pair strategy and 2SLS.

	(1)	(2)	(3)
	lnCOD	*lnMW*	*lnCOD*
lnIV		0.9913^{***}	
		(0.0062)	
lnMW	0.4313*		0.5141^{**}
	(0.2365)		(0.2223)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County pair FE	Yes	No	No
County FE	No	Yes	Yes
Industry FE	Yes	Yes	Yes
N	104337	120833	120833

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 8

Heterogeneity analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	SOEs	Non-SOEs	Higher labor-intensive industries	Lower labor-intensive industries	Strong labor protection regions	Weak labor protection regions
lnMW	-0.4501	0.6231***	0.6009**	0.4009	1.5603*	0.4039
	(0.3803)	(0.2415)	(0.2819)	(0.2737)	(0.8587)	(0.2525)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-5.4980	-0.6897	1.2381	-3.1096	-10.0172	0.3808
	(7.6145)	(5.0983)	(4.7811)	(7.2169)	(17.9867)	(4.1865)
N	14284	118026	76133	56863	40045	74323
Adjusted R2	0.7315	0.7423	0.7640	0.7028	0.7572	0.7584

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 9

Mechanism 1: factor substitution and energy consumption.

Variable	(1) Labor	(2) Capital Intensity	(3) Energy consumption	(4) COD yield
lnMW	-0.0580**	0.0577*	0.1834*	0.6658***
	(0.0284)	(0.0297)	(0.1111)	(0.2518)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Constant	2.5168***	-4.8654***	2.4143	1.9865
	(0.5939)	(0.6788)	(2.2162)	(3.9051)
N	132568	132051	133701	133750
Adj R2	0.8697	0.8630	0.7972	0.7748

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 10

Mechanism 2.1: Financial constraint and innovation limit.

	(1) Financial constraint	(2) Invention patent	(3) Utility patent	(4) Design patent	(5) Total patent	(6) $\frac{\text{COD yield}}{\text{Output}}$
lnMW	0.0542*	-0.0214**	-0.0045	-0.0097	-0.0223	0.4759***
	(0.0319)	(0.0091)	(0.0089)	(0.0087)	(0.0146)	(0.1460)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.4244***	-0.0547	0.0540	0.1876	0.0338	1.8408
	(0.6627)	(0.1550)	(0.1849)	(0.1475)	(0.2693)	(2.7069)
N	121216	126209	126209	126209	126209	92407
Adj R2	0.7870	0.3243	0.3508	0.3133	0.3756	0.8323

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.

Table 11

Mechanism 2.2: Financial constraint and restrain abatement investment.

	(1) Abatement equipment	(2) COD removal ratio
lnMW	0.0465	0.0739
	(0.0509)	(0.0855)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
County FE	Yes	Yes
Industry FE	Yes	Yes
Constant	-0.4536	0.9065
	(0.7906)	(1.7777)
N	63139	132965
Adj R2	0.1171	0.6605

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at the county level are reported in parentheses.