北京大学-林肯研究院城市发展与土地政策研究中心

2015-2016 年度研究基金

The cost of APEC BLUE：
The impact of environmental regulation on labor demand

张 炳

南京大学 环境管理与政策研究中心

2016 年 7 月 1 日

1. Introduction

Air pollution has been one of the most pernicious consequences of China’s last three decades of economic transformation and growth. In China, air pollution, measured by the ambient concentrations of particulate matter (PM) and sulfur dioxide (SO_2), is among the worst in the world. According to a report by RAND Corporation, in the past decade, the environmental pollution cost is accounted for 10% of GDP per year in China, which is several times higher than in developed Asian market economies such as Korea and Japan, and also higher than in the United States (Crane and Mao 2015). The high costs of air pollution mainly stem from its effect on human health. In China, concentrations of pollutants exceed standards recommended by the World Health Organization (WHO) in virtually every major urban area. All major Chinese cities exceed WHO air quality standards for major pollutants except for a few that meet WHO standards for nitrogen oxides; most exceed average daily limits for PM10 by five times or more (Crane and Mao 2015). Air pollution is believed to kill more people worldwide than AIDS, malaria, breast cancer, or tuberculosis. Airborne particulate matter (PM) is especially detrimental to health. For example, a recent study found that in China, life expectancy decreases by 3 years for each 100 microgram increase in total suspended particulates of all sizes (Chen et al. 2013).

The rapid deterioration of environmental quality in China, thus, raise great concerns and warrant more stringent environmental regulation. According to China’s National Bureau of Statistics, the total investment in treatment of environmental pollution increased from $ 16.8 billion USD in 2001 to $144.7 billion USD (1.67% of GDP) in 2013. This shift in focus from just economic growth to economic growth and a cleaner environment as China’s per capita income increases is consistent with the Environmental Kuznets Curve hypothesis. Since most of China’s air pollution issues are due to the economy’s heavy reliance on the manufacturing sector and in particular highly polluting industries[1], to continue its fast-paced economic growth (Vennemo, Aunan et al. 2009), during the 10th (2001–2005) Five-Year Plan (FYP), the reduction of industrial pollutants was one of the main tasks. Sulfur dioxide (SO_2), the main target for the atmospheric environment, was required to reduce 10%. Also, during the 11th (2006-2010) Five-Year Plan (FYP), SO_2 was again required to reduce 10% below 2005 levels. A comprehensive control policy focusing on multiple pollutants and emission sources at both the local and regional levels was proposed to mitigate the regional air pollution issue in China. The options include development of clean energy resources, promotion of clean and efficient coal use, enhancement of vehicle pollution control, implementation of synchronous control of multiple pollutants including SO_2, NOx, VOC, and PM emissions, joint prevention and control of regional air pollution, and application of climate friendly air pollution control measures. Actually, according to official statistics, China has already made some progress in reducing emissions of TSP, SO_2, and NOx, resulting in some improvements in air quality in major cities.

While, on the other hand, the potential impact of environmental regulation on employment in China is an extremely important issue that looms large in environmental policy debates, and which has attracted more political attention since the beginning of the Great Recession. During the Great Recession, the exports of several key Chinese industries experienced large negative shocks. For example, the export of steel and high-tech products fell by 53.8% and 28% respectively. With the decline of industrial production, China's already heavy burden to constantly create hundreds of thousands of new jobs each month just to keep unemployment from increasing became that much greater. Moreover, at the same time, 450 million workers are expected to migrate from rural areas to urban areas within the next 20 years, which will create further pressure on the government to continue fast-paced economic growth. Given that an increasing number of strikes and protests, mainly caused by the

[1] Figure A1 and Figure A2 in the appendix show that manufacturing output and employment have, in general, been increasing steadily over the past 15 years. Moreover, output in heavily polluting industries has been growing steadily as well, and this has come with a high environmental price.

systematic failure of employers to respect the basic rights of employees, have occurred in recent years, the added uncertainty of potential job losses due to stricter environmental regulation may also face heavy opposition by manufacturing workers, making it more difficult to increase the stringency of environmental regulations. However, compared to developed countries, developing countries, including China, are just beginning to figure out how to balance economic development with the desire to address numerous severe environmental problems.

Popular thinking is that the Chinese government is facing a hard tradeoff between creating jobs and environmental protection, which is consistent with the mainstream view that pollution reduction will lead to job losses in the directly regulated sectors. The economic reasoning behind this claim is that more stringent environmental regulation leads to higher production costs, which causes enterprises to raise prices thereby lowering demand for its output, thereby reducing demand for inputs, including labor (this is referred to as the output effect). However, what this argument fails to recognize is that for enterprises to comply with the new, more stringent regulations, they must install pollution abatement equipment, or alter their production process to produce less waste, which may require more or less labor than prior to the regulation (this is referred to as the substitution effect). Standard neoclassical microeconomic theory cannot predict ex ante which of these effects will dominate, therefore, the impact of environmental regulation on employment in the directly regulated sector is uncertain and thus requires empirical investigation (Berman and Bui 2001).

The impact of environmental regulation on labor demand is an important issue and has been widely discussed in developed countries. Most existing empirical studies using either plant-level or industry-level data from the United States and Western Europe have found relatively small impacts of environmental regulation on labor demand in the directly regulated industry. This indicates that environmental regulations in developed countries have led to negligible negative effects on employment. Unlike the studies mentioned above, in this paper we focus on the labor demand effects of environmental regulation in a developing country. In particular, we focus on how China’s Key Environmental Protection City policy affects employment.

The main objective of our empirical analysis is to estimate the effect of the Key Environmental Protection City policy on environmental performance and employment. Using a balanced panel data set, we examine the impact of environmental regulation on pollution reduction and labor demand using an estimation technique that pairs city-level propensity score matching (PSM) with a difference – in - differences (DID) estimator.

We find that the new environmental regulation is effective in terms of reducing SO2 emissions (-15%). Our results also show that the new environmental regulation has led to significantly lower levels of employment in the manufacturing sector in the KEPCs - employment fell by 3-6% relative to compared enterprises in the non-KEPCs. Furthermore, we find that the new standard had heterogeneous impacts on different types of enterprises. For example, our results indicate that the KEPC policy has particularly large negative effects on employment in domestic private enterprise, old enterprises and enterprises in some specific industries.

The following section provides institutional background about the Key Environmental Protection City policy. In section 3 we provide our conceptual framework and brief literature review on extant empirical findings. Section 4 describes our empirical strategy and section 5 presents our data sets. In section 6 we present the main empirical results and a set of heterogeneity analyses, while section 7 presents a series of robustness checks. Section 8 contains our conclusions and future work.

2. Key Environmental Protection City

The Chinese central government has a variety of mechanisms for establishing environmental policies and transmitting them to local governments. In addition to directly setting standards in laws and regulations, another mechanism is to select locales for priority treatment. Actually, China has a long history of appointing priority locales, most of which are economic labels, such as the Special Economic Zone (SEZ) - one of the greatest powerhouses of the post 1979 Reform and Opening, the High-technology Development Zone, etc. There are also some environmental labels – some like “green city” and “environmentally friendly city” are awards for good performance, others like the Key Environmental Protection City (KEPC) are both a signaling device, intended to encourage better performance from an important set of localities and a mechanism for focusing the use of environmentally-friendly, but limited or costly, policy changes.

The concept of Key Environmental Protection City (KEPC) was firstly put forward in 1998. According to an official document (known as “two compliance policy”) of the State Environmental Protection Administration (now the Ministry of Environmental Protection)[2], 47 prefectural-level cities[3] were designated as the first batch of “Key Environmental Protection City,” most of which are municipalities, provincial capital cities, cities in Special Economic Zones (SEZ), coastal open cities, and major tourist cities. The 47 KEPCs were required to reach the National Ambient Air Quality Standard (GB3095-96) and the National Surface Water Environmental Quality Standard

[2] Official document, see http://www.zhb.gov.cn/gkml/zj/wj/200910/t20091022_171905.htm

[3] They are Beijing, Tianjin, Shanghai, Chongqing, Shijiazhuang, Taiyuan, Hohhot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chengdu, Guiyang, Kunming, Xi’an, Lanzhou, Yinchuan, Xining, Urumchi, Shenzhen, Zhuhai, Shantou, Xiamen, Dalian, Qinhuangdao, Suzhou, Nantong, Lianyungang, Ningbo, Wenzhou, Zhanjiang, Beihai, Qingdao, Yantai, Guilin.

(GB3838-88) by 2000. The assessment indicators are TSP, SO_2, and NOx[4] for air quality, and DO and permanganate index for water quality.

In China's 10th Five-Year National Environmental Protection Plan[5], the number of key environmental protection cities expanded from 47 to 113[6]. The choice of cities was mainly based on The Law about Prevention and Treatment of Air Pollution[7]. Based on the analysis of the present air pollution level and comprehensive economic situation in 2000, cities being appointed to be the KEPC mainly according to the following considerations:

a) Cities who were required to reach the standard of "The tenth five-year plan for acid rain and SO_2 pollution prevention and control (known as Two Control Zone, TCZ)" by 2005.
b) Cities whose air quality exceed standard but are expected to reach the standard by 2005.
c) Cities whose culture are in urgent need of protection.

The 113 cities were required to make progress to reach (or keep up) the National Ambient Air Quality Standard (GB3095-96)[8] by 2005 mainly through speeding up the urban energy structure adjustment, carrying out clean production, strengthening the supervision and management of motor vehicle emissions, controlling the dust pollution of city construction sites and road transport, etc. Though the 113 KEPCs were assigned mainly based on air quality situations, after the designation, requirements were extended to reaching water environmental quality as well[9].

---

[4] NOx was not required in western region.

[5] Official document, see http://www.zhb.gov.cn/gkml/zj/wj/200910/t20091022_172232.htm

[6] The list of 113 KEPCs is showed in appendix.

[7] Work report, see http://www.zhb.gov.cn/info/ldjh/200307/t20030703_86927.htm
Selection scheme, see http://wfs.mep.gov.cn/dq/gzjz/200302/t20030213_84369.htm

[8] Among the 113 cities, 39 cities had already met the standard before the policy being implemented, while the other 74 cities hadn't.

[9] Work report, http://www.zhb.gov.cn/info/ldjh/200307/t20030703_86927.htm

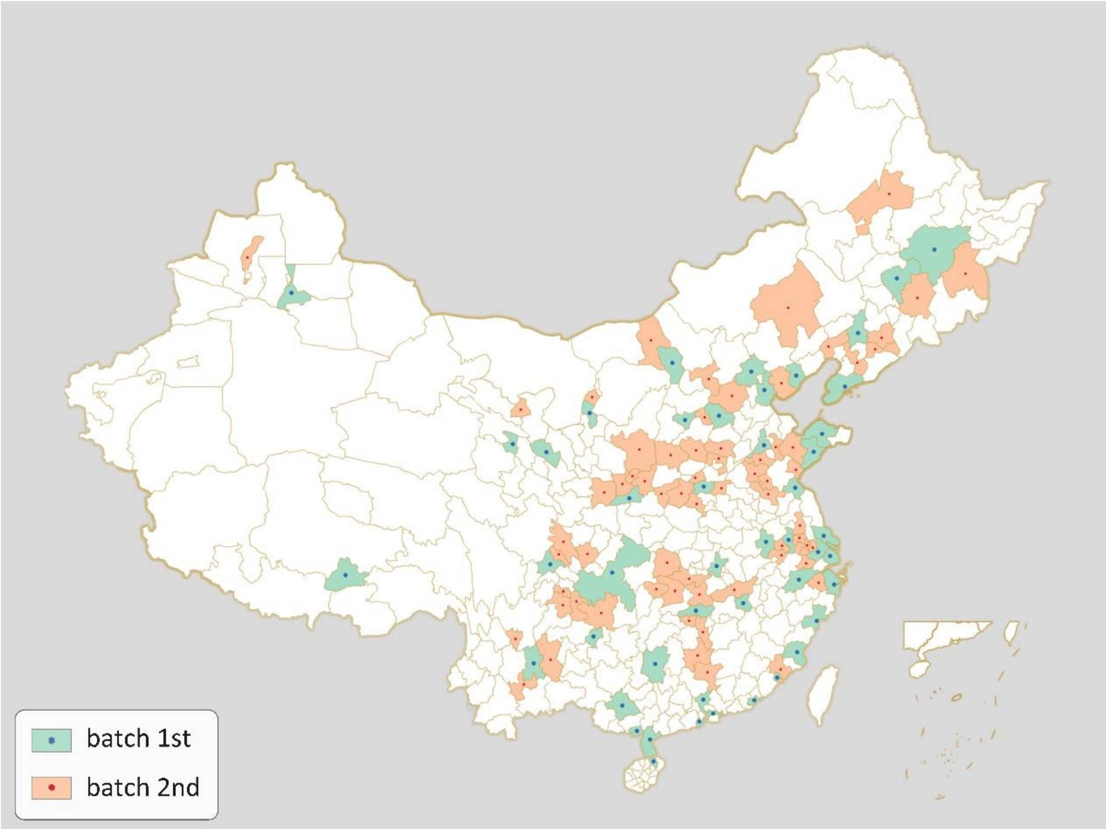

Figure 1: The distribution of Key Environmental Protection City

3. Environmental Regulation and Employment

3.1 Conceptual Framework

Among non-economists the dominant view is that more stringent regulations leading to pollution reduction must reduce employment in the directly regulated industry, because greater levels of pollution abatement increases production costs, which would raise prices and reduce demand for output, and thus reduces employment. However, standard neoclassical microeconomic analysis demonstrates that this is not necessarily true. Berman and Bui (2001) demonstrate that the effect of environmental regulation on employment in the directly regulated sector can be decomposed into two separate mechanisms, the output effect and the substitution effect. It is generally believed that the output effect is negative – more stringent environmental regulation leads to higher production costs, which causes the plant to reduce its output, thereby reducing demand for inputs including labor. On the other hand, the substitution effect is ambiguous. In order to comply with more stringent environmental regulations, plants must implement new pollution reduction activities. Abatement activities fall into two main categories: ‘end-of-pipe’ and ‘change in production process.’ ‘End of pipe’ techniques such as installation of flue gas desulfurization units, water treatment facilities and sewage disposal facilities could require more labor to install, operate and maintain the equipment, thereby having a positive effect on labor demand. While, ‘change in production process’ such as the installation of more efficient boilers that produce less pollution could reduce labor demand due to a general skill-bias of this technological change. Thus, according to Berman and Bui’s (2001) analysis, the overall effect of more stringent environmental regulation on employment is uncertain from theory alone and therefore requires empirical analysis[10].

3.2 Empirical Findings

Greenstone (2002) uses a difference-in-differences model with plant-level data from the U.S. manufacturing sector from 1972 to 1987 to examine the effects of county nonattainment status with respect to National Ambient Air Quality Standards on employment. He found that the first 15 years of the 1970 Clean Air Act Amendments led to a loss of approximately 600,000 jobs in nonattainment counties compared to attainment counties. However, this estimate is a gross effect and not a net effect. In other words, Greenstone’s findings do not indicate that there is less total employment due to environmental regulation; instead his results imply that the relative growth rate of employment in some industries may differ between attainment and non-attainment

[10] Morgenstern, Pizer and Shih (2002) use a similar model but disaggregate the employment effect into three components: the demand (output) effect; the cost effect; and the factor-shift effect. Others believe that the impact of pollution reduction on labor demand is not a simple linear relationship, which may also depends on the initial level of pollutants contamination (Bovenberg and van der Ploeg 1996).

counties. Similarly, Walker (2011, 2013) finds statistically significant gross employment losses in nonattainment counties relative to attainment counties.

Berman and Bui (2001) use plant-level data to estimate the effect of air pollution regulations on labor demand in the South Coast Air Quality Management District (SCAQMD) in California, one of the most highly regulated areas in the United States. They find evidence suggesting that air quality regulations in the SCAQMD did not reduce the demand for labor and possibly increased it. Gray et al. (2014), using plant-level data, examine how EPA’s 1997 Cluster Rule affected labor demand in the pulp and paper industry. They find evidence of small reductions in employment (i.e., 3 to 7 percent), but these effects are not always statistically significant. Ferris, Shadbegian, and Wolverton (2014), examine the impact of EPA’s SO_2 trading program on employment at fossil fuel fired power plants. They find little evidence that the first phase of the SO_2 trading program led to significant decreases in employment at regulated fossil fuel fired power plants.

Cole and Elliott (2007) and Gray and Shadbegian (2014) both use a similar model to Berman and Bui (2001) with industry-level data. Cole and Elliot found that environmental regulation (measured by pollution abatement costs as a percentage of gross value-added and pollution abatement capital expenditures as a percentage of total capital expenditures) have no significant effect on labor demand in the United Kingdom from 1999 to 2003. Similarly, Gray and Shadbegian, using pollution abatement operating costs relative to output to measure the stringency of environmental regulation, find evidence of a statistically significant yet quite small effect of regulation on U.S. manufacturing employment. There are also some studies which have examined the effect of the EU ETS (EU Emission Trading System) on employment and generally found no statistical evidence that environmental regulation decreased employment (Anger and Oberndorfer 2008; Abrell, Ndoye Faye et al. 2011; Chan, Li et al. 2013).

To sum-up, most existing empirical studies using either plant-level or industry-level data from the United States and Western Europe have found relatively small impacts of environmental regulation on labor demand in the directly regulated industry. This indicates that environmental regulations in developed countries have led to negligible negative effects on employment. Unlike the studies mentioned above, in this paper we focus on the labor demand effects of environmental regulation in a developing country. In particular, we focus on how China’s Key Environmental Protection City policy affects employment.

4. Empirical strategy

The main objective of our empirical analysis is to estimate the effect of the Key Environmental Protection City policy on environmental performance and employment. Using a balanced panel data set, we examine the impact of environmental regulation on pollution reduction and labor demand using an estimation technique that pairs city-level propensity score matching (PSM) with a difference-in-differences (DID) estimator. We first use a PSM technique (developed by Rosenbaum and Rubin 1983) based on pre–KEPC attributes of cities to select a statistically defensible comparison group from untreated cities. Then, we use DID estimation to investigate how KEPC policy affected enterprise-level employment relative to what occurred prior to the policy for the control group.

4.1 DID approach

As described above, the very ambitious improvement in air and water quality required by the 10^{th} Five-Year National Environmental Protection Plan were firstly achieved in 113 KEPCs. Among the 113 KEPCs, 47 cities are the first batch of KEPC designated in

1998 while the rest 66 cities were newly designated in 2001. This will let us estimate the causal effect of the new regulation on employment and pollution reduction with good precision using DID models. The DID estimator has the advantage of differencing out pre-existing variation between enterprises in the 66 newly designated KEPCs and enterprises in non-KEPCs thereby reducing selection bias, while also controlling for potentially confounding factors that may have changed around the time of the 10^{th} Five-Year that could have affected both sets of enterprises. Furthermore, the inclusion of enterprise fixed effects allows us to control for any unobserved time invariant differences giving us more confidence to interpret our estimate of the new policy on labor demand causally. The resulting DID estimate is the average treatment effect of the KEPC policy on employment in regulated enterprises before and after the regulation became effective relative to the control group.

The enterprises in the control group need to satisfy two conditions. First, these enterprises should not be affected by the regulation, which can be ensured because the scope of policy is very clear and we know each enterprise’s detailed address. Second, in order to eliminate selection bias, the enterprises in our control group should, absent the regulation, be very similar to the treated enterprises as well as pre-regulation trends. In order to achieve a more similar control group, we select control group using PSM (for detailed information, see Section 4.2).

Environmental policy in China has long been considered ineffective (Alford 1997). For example, certain classes of enterprises in China have strong bargaining power over local environmental authorities, which leads to incomplete enforcement of environmental regulations. Wang et al. (2003) examined the determinants of monitoring and enforcement of water pollution in China and found that state-owned enterprises, enterprises facing adverse financial situation, and enterprises facing less social impact (as measured by the presence and number of complaints) have more bargaining power with local environmental authorities. So the efficacy of enforcement environmental regulation in China is uncertain. Therefore, before we test the effect of the new wastewater discharge standard on labor demand, we first test the efficacy of the KEPC policy by using the following DID model for the log of SO2 emission:

$$ln(SO2)_{it} = \alpha_i + \gamma_t + \eta_{jt} + \omega_{rt} + \beta_1 KEPC_i \times Post2001_t + \beta_2 KEPC_i + \beta_3 Post2001_t + \varepsilon_{it} \quad (1)$$

where i indexes enterprises, j indexes 2-digit National Standard Industrial Classification (NSIC) industries (e.g. textiles, food manufacturing, paper and paper products, chemical fiber manufacturing, etc.), and t indexes years. $ln(SO2)_{it}$ is the logarithm of SO_2 emissions. $KEPC_i$ equals 1 if an enterprise is located in KEPCs otherwise it equals 0, therefore β_2 captures the average difference in SO_2 emissions between the KEPCs and non-KEPCs enterprises that is common to both the pre-policy and policy periods. $Post2001_t$ equals 1 for all years after 2001 (the policy period), otherwise it equals 0, thus β_3 captures the average change in SO_2 emissions from the pre-policy to the policy period that is common to both KEPCs and non-KEPCs enterprises. $KEPC_i \times Post2001_t$ is the interaction term between the $KEPC_i$ and $Post2001_t$, which captures the average differential change in SO_2 emissions at KEPCs enterprises relative to the control group. Thus, the coefficient β_1 measures the difference-in-differences effect, where:

$$\begin{aligned} \beta_1 = &(ln(SO2)_{KECP=1,Post2001=1} - ln(SO2)_{KEPC=1,Post2001=0}) \\ &-(\ln SO2)_{KEPC=0,Post2001=1} - ln(SO2)_{KEPC=0,Post2001=0}) \end{aligned} \quad (2)$$

If β_1 is significantly negative, we can infer that the policy effectively reduced SO2 emissions. We take advantage of the panel nature of our data by including enterprise fixed effects (α_i) and time fixed effects (γ_t) in our basic specification.[11] The inclusion of the time and enterprise fixed effects means that we now control for general macroeconomic factors that affect all enterprises over time as well as enterprise-specific characteristics which are time invariant. In some of the specifications we also include a set of industry fixed effects or industry-year fixed effects, which controls for industry-specific factors.[12] We also add a set of region fixed effects or region-year fixed effects in some of the specifications[13]. ε_{it} is the usual idiosyncratic error term. In all regressions, we cluster standard errors at the enterprise level.

After we estimate the effect of the KEPC policy on pollution reduction we estimate the effect of environmental policy on our main outcome variable of interest employment, measured by the log of the number of employees, using a similar DID model. The DID regression model we estimate for employment is:

$$ln(Labor)_{it} = \alpha_i + \gamma_t + \eta_{jt} + \omega_{rt} + \beta_1 KEPC_i \times Post2001_t + \beta_2 KEPC_i + \beta_3 Post2001_t + \varepsilon_{it} \quad (3)$$

where $ln(Labor)_{it}$ is the outcome variable. The meaning of other variables remain same with equation (1). Similarly, it is β_1 that measures the difference-in-differences effect of environmental regulation on labor demand, where:

[11] In some models we drop the time fixed effects and add in a quadratic time trend, so we can identify the coefficient on Post2001.

[12] We use 2-digit National Standard Industrial Classification (NSIC) code to measure the differences of industry.

[13] We divide the whole country into four regions according to the geographical divisions of the country, i.e., northeastern region, eastern region, central region and western region.

$$\beta_1 = (ln(Labor)_{KECP=1,Post2001=1} - ln(Labor)_{KEPC=1,Post2001=0}) \\ - (ln(Labor)_{KEPC=0,Post2001=1} - ln(Labor)_{KEPC=0,Post2001=0}) \quad (4)$$

4.2 Select control group using PSM

Propensity score matching uses a logist regression (the dependent variable is equal to 1 for KEPC and 0 otherwise) where the independent variables are pretreatment characteristics that may affect the “propensity” to be designated in the KEPC. Cities are matched with their nearest neighbor (NN) according to the propensity score, which is a scalar summary of pretreatment characteristics from the logist regression.

$$\|P_i - P_j\| < \varepsilon, j \in J_0 \quad (5)$$

where P_i is propensity score of city i in treatment group, P_j is propensity score of city j in control group, J_0 is the collection of control group, and ε is caliper size (we set caliper to be 0.1 in our preferred estimates). The propensity score predicts a city’s probability of being designated in the KEPC, $P(\mathrm{X}) \equiv \Pr(\mathrm{D}=1|\mathrm{X})$, for a set of given observable characteristics X. As discussed above, cities being appointed to be the KEPC mainly based on the present air pollution level and comprehensive economic situation in 2000. Specifically, whether a city was in TCZ, whether a city’s air quality exceeded the air quality standard but was expected to reach the standard, and whether a city’s culture was in urgent need of protection. Thus, we use city’s **population** and **GDP per capital** as indicators of comprehensive economic situation and use **industrial SO_2 emissions** and **intensity of industrial SO_2 emissions per unit of area** as indicators of air pollution level. We also include **TCZ dummy**[14] (TCZ is equal to 1 if a city is in the Two Control Zone and 0 otherwise) and **NFHCC dummy**[15] (NFHCC is equal to 1 if a city is in the National Famous Historical and Cultural City list and 0

[14] The list of TCZ cities is showed in appendix.

[15] The list of NFHCC is showed in appendix.

otherwise). Figure 2 shows the distribution of treatment cities and matched control cities.

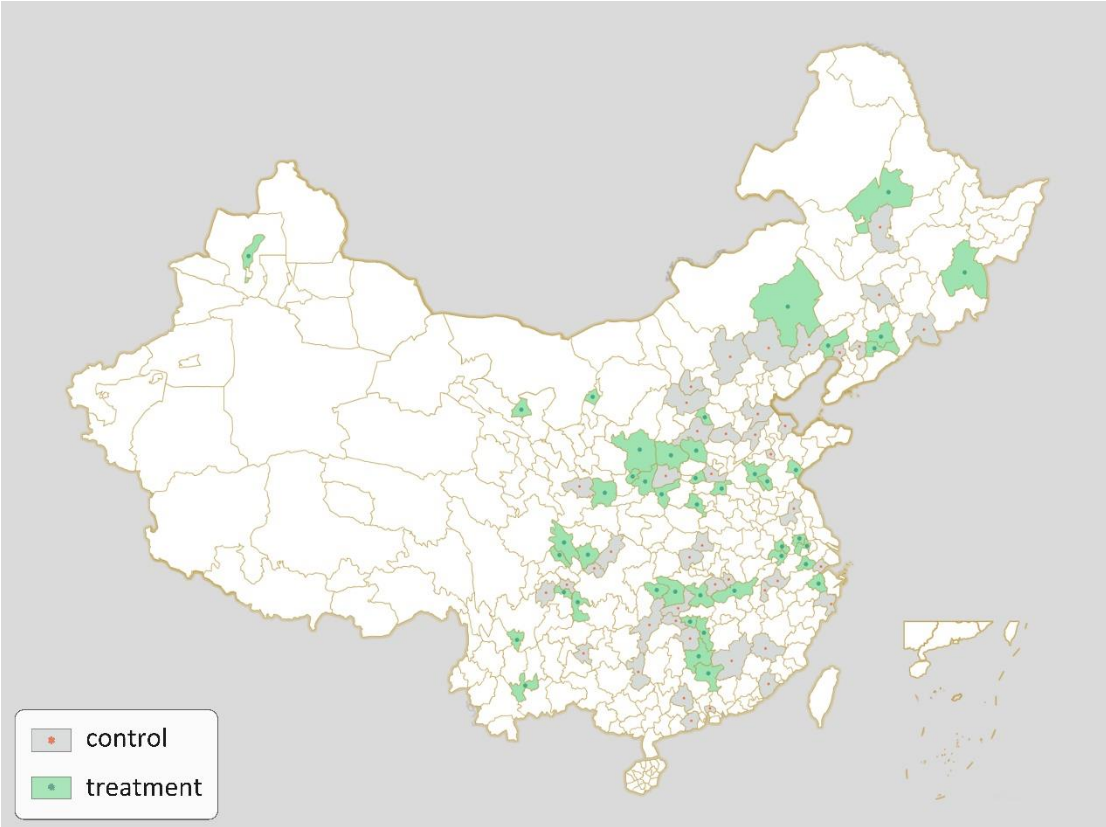

Figure 2: The distribution of treatment group and matched control group

In Section 7 below, we demonstrate that our main results are robust using an alternative PSM strategy as a robustness check. In order to consider differences between regions, we change our matching strategy to restrict the treated city and the matched city being from a same region. Given the big differences among China, we then divide the whole country into four regions according to the geographical divisions of the country, i.e., northeastern region, eastern region, central region and western region[16].

[16] Northeastern region includes Liaoning, Jilin, Heilongjiang. Eastern region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan. Central region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan. Western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

5. Data

5.1 Data sources

To estimate the impact of the KEPC policy on pollution reduction and employment we construct an enterprise-level balanced panel dataset from 2000 to 2007. Before that we use city-level data in 2000 to do the PSM. Our analytical dataset is derived from two enterprise-level data sources: China's Environmental Statistics Database (CESD) and China's Industrial Enterprise Database (CIED) and a city-level data sources: China City Statistical Yearbook (CCSY).

The CESD is the most extensive environmental data set in China providing nationwide data.[17] The Ministry of Environmental Protection (MEP) has establish a system to collect environmental information covering all the major industrial emission sources in China. The data is self-reported by the sources seasonally and then is compiled by the MEP.[18] Local Environmental Protection Boards (EPB) at the county level ensure data quality by conducting monitoring activities and unannounced field inspections. The EPBs then produce a final report which is submitted to the environmental protection department at the (provincial level).[19] After careful inspection the verified environmental information is finally submitted to the MEP after which the various environmental protection departments can publish their annual environmental status reports based on the raw micro-data. Due to the strict data quality procedures, the CESD is the most reliable environmental micro-data set in China. The CESD covers 3 industrial sectors – mining, manufacturing, and the electricity, heat and water production and supply – and 39 2-digit National Standard Industrial Classification (NSIC)

[17] China started collecting environmental statistics on the industrial pollutants and waste in the 1980s. However, the CESD was kept confidential for a long time and has only recently become available to researchers.

[18] Key national enterprises, as classified by the MEP, must report the required data every season.

[19] Note there are three levels of government which regulate the environment in China – national level (MEP), provincial level and local level.

industries (e.g. textiles, food manufacturing, paper and paper products, chemical fiber manufacturing, etc.).[20,21] The CESD covers approximately 85% of the annual emissions of COD, NH_3, SO_2, NO_x, TSP in each county and each year. The CESD contains more than 400 data fields, which are updated annually. In particular, the following information is included in this dataset: 1) basic enterprise information (e.g. the legal person code[22], name, administrative district code and industry code); 2) basic production information (e.g. the operation time and total output value); 3) pollution emissions (e.g. emissions of COD, NH_3, SO_2, NO_x, TSP); and 4) environmental equipment (e.g. number of wastewater treatment facilities, waste gas treatment facilities and desulphurization units) and other environmental-relevant information of the enterprises (e.g. pollutant removal, treatment capacity, and operating costs of pollution facilities).[23] We use information on COD discharges and SO_2 emissions from this data set.

The CIED is another large data set, widely used by China’s microeconomic researchers (see, for example, Hsieh, Klenow, 2009; Brandt, Van Biesebroeck et al. 2012), which contains a tremendous amount of information on production and finances of all industrial enterprises above a certain size. Data on all state-owned and non-state-owned enterprises, which have an annual business income above 5 million CNY, are collected in the CIED. The total output of enterprises in the CIED accounts for approximately 90% of China's total industrial output.[24] The CIED contains more than

[20] We focus on textile industry, whose 2-digit industry code is 17.

[21] Tap water production and supply industry, hydroelectric power, and soil sand mining industries are not included in CESD.

[22] This is something like enterprises’ ID and it is used to identify enterprises. Enterprise names are often very long and one or two words in them may change over time, so the legal person code is useful to link data sets over time.

[23] Ma (2010) used part of this data set (data for Henan province) to analyze whether environmental inequality exists in China. Wu et al. (2016) used this data set to analyze the location choice of new polluting enterprises driven by the 11^{th} Five- Year Plan’s water pollution mandates.

[24] The CIED covers more than 40 (2 digit NSIC) industries and more than 600 (4 digit NSIC) sub-industries.

a hundred of variables related to various economic and financial indicators, such as industrial output and value-added, ownership type, as well as number of employees. For our empirical analysis, we extract the number of employees, value of industrial output and exports, the year operations started, and industry classification from this data set.[25]

CCSY is an annual city-level statistical publication conducted by National Bureau of Statistics of China (NBSC) covering the main socio-economic statistical data of 658 cities (including 289 cities at prefecture level and above, and 369 cities at county-level). The CCSY contains 10 aspects related to main social and economic information, including Divisions of administrative areas population, labor forces and land resources, General economy, Industry, Transport, postal and telecommunication services, Trade, foreign trade and economic cooperation, Investment in fixed assets, Education, culture and public health, People’s living conditions and social security, Municipal public utilities and Environmental protection.

5.2 Descriptive statistics

We obtain our manufacturing enterprise-level balanced panel data from 2000 to 2007 after a series of standard procedures in the literature. First, we drop observations with missing values or with negative values for output, employment, and SO_2 emissions. Second, we drop observations with employment less than 10, because these small enterprises may not have a reliable accounting system. Third, we drop observations that apparently violate accounting principles: liquid assets, fixed assets, or net fixed assets larger than total assets; current depreciation larger than accumulative depreciation. Considering that we focus on high SO_2 polluting enterprises, enterprises who produce no SO_2 emissions in any of the years during 2000-2007 are also excluded

[25] Our enterprise age variable is statistical year minus opening year. We would like to use work hours and number of workers by type of job, but unfortunately we do not have access to it.

in our sample[26]. We finally get 1,363 manufacturing enterprises per year in the CESD, leading to 10904 enterprise-year observations from 2000 to 2007. For CIED, we get Table 1 presents the brief description of each variable, the acronym we use in our analysis and data sources. Table 2 shows the summary statistics (mean value, standard deviation, min value, max value, and observations) of enterprises' main characteristics we use. There are on average 455 employments per enterprise per year. The average annual SO_2 emission is approximately 292,048 kilogram per enterprise and the average annual COD emission is approximately 137,067 kilogram per enterprise. The average annual output value is 128,808 thousand CNY. It is evident from Table 2 that the enterprises in our sample exhibit great variations in almost every variable.

[26] We also change the condition to only exclude enterprises whose SO2 emissions were 0 for all the years during 2000-2007 as a robustness check.

Table 1 Variable definitions and data sources

Variable	Definition	Data Source
Labor	the number of employees, person	China’s Industrial Enterprise Database, 2000-2007
SO_2	annual sulfur dioxide emissions, kilogram	China’s Environmental Statistics Database, 2000-2007
COD	annual chemical oxygen demand emissions , kilogram	China’s Environmental Statistics Database, 2000-2007
Age	statistical year minus opening year, year	China’s Industrial Enterprise Database, 2000-2007
Population	register population at 24 clock, December 31, of the reporting year	China City Statistical Yearbook, 2000
GDP per capital	per capital final products at market prices	China City Statistical Yearbook, 2000
Industrial SO2	the aggregate of industrial sulfur dioxide emission to the air during the production and fuels combustion at factory	City-level China’s Environmental Statistics Database, 2000
Area	all land and water area under city	China City Statistical Yearbook, 2000
TCZ	whether a city is in the scope of the Two Control Zone	The state council document, 1998
NFHCC	whether a city is in the list of the National Famous Historical and Cultural City	The state council document, 1982, 1986, 1994

Table 2 Summary statistics

Variable	Mean	St.Dev.	Min	Max	Obs
SO_2	292048.50	2194336.00	1.00	83700000.00	10904.00
ln(SO2)	10.34	1.95	0.69	18.24	10904.00
COD	137067.20	780572.80	0.00	21800000.00	10373.00
ln(COD)	7.43	4.37	0.00	16.90	10373.00
Labor	455.44	1341.99	11.00	100185.00	87512.00
ln(Labor)	5.34	1.11	2.40	11.51	87512.00
Output	128808.30	756518.00	18.00	44500000.00	87512.00
ln(Output)	10.51	1.28	2.94	17.61	87512.00

To be more intuitionistic, Figure 3 and Figure 4 show the distributions of SO_2 emission and labor demand for treatment group and control group before and after the policy. Since we take the log of SO_2 emission and labor demand, we achieve normal distributions well. As shown in Figure 3, SO_2 emission in both treatment group and control group show slight decline trends after the policy. This comparison, while implying the difference in SO_2 emission level between the two groups, indicates a possible policy effect which needs to be further tested by our DID model. Another concern is the effect of environmental regulation on labor demand. We find that enterprises in the two groups have similar labor demand and the changes are relatively small.

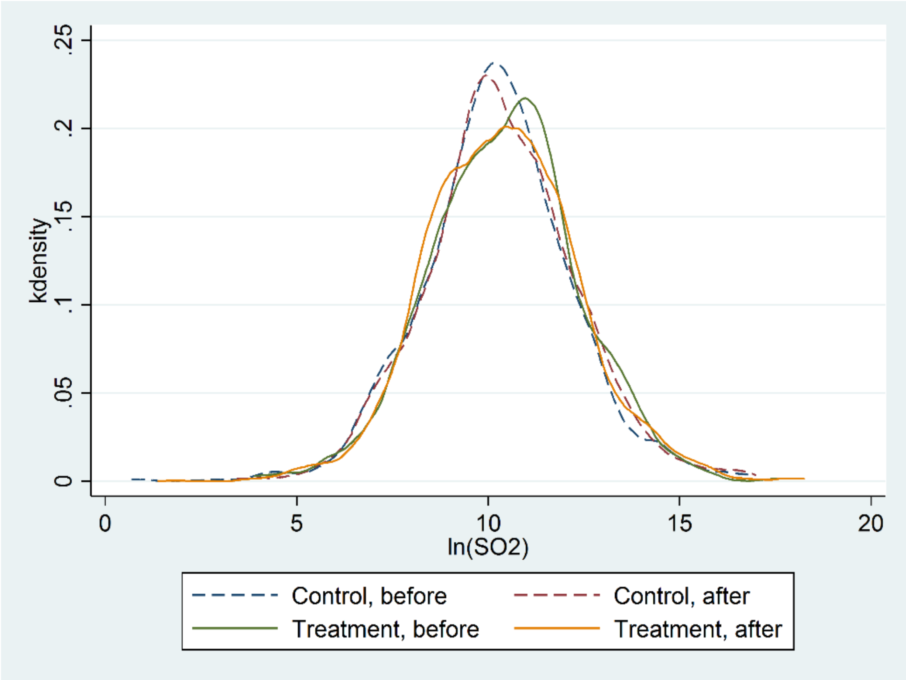

Figure 3: Kdensity of ln(SO2)

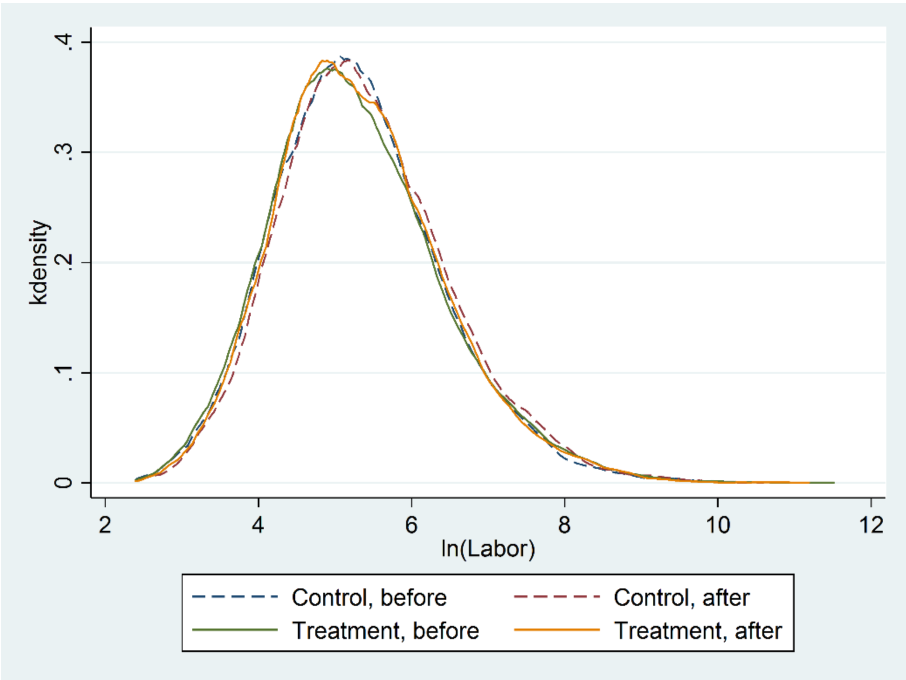

Figure 4: Kdensity of ln(Labor)

6. Results

6.1 Checks on the identification assumption

Whether the results of our DID model captures the causal effects of the KEPC policy on SO_2 emissions and employment hinges on the satisfaction of the strong identification assumption that the treatment group would have followed the same trend as the control group absent the new environmental policy. Figure 5 and Figure 6 illustrates the year-to-year changes of mean values of SO_2 emissions and employment of enterprises in both our treatment and control groups from 2000 to 2007. As the figures show, though the KEPC enterprises have higher SO_2 emissions relative to the control group, the trends of SO_2 emissions and labor demand for the two sets of enterprises are very similar prior to the policy change starting from 2002. This finding reassures us that KEPC enterprises and the set of control group enterprises selected using PSM technique would have followed the same trends after 2002 in the absence of the new KEPC policy.

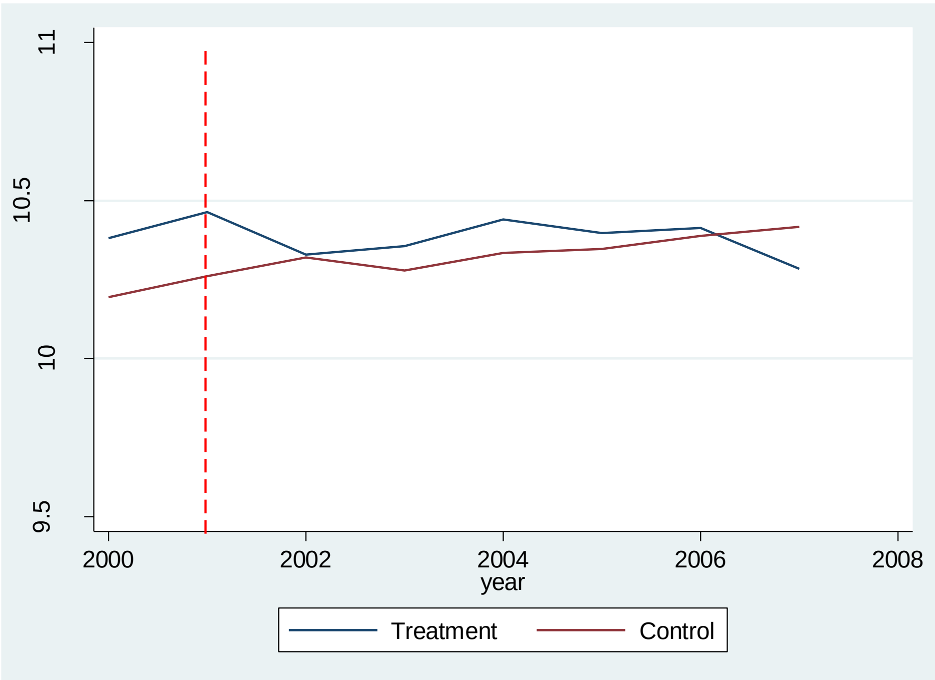

Figure 5: Trends of SO_2 emissions over time

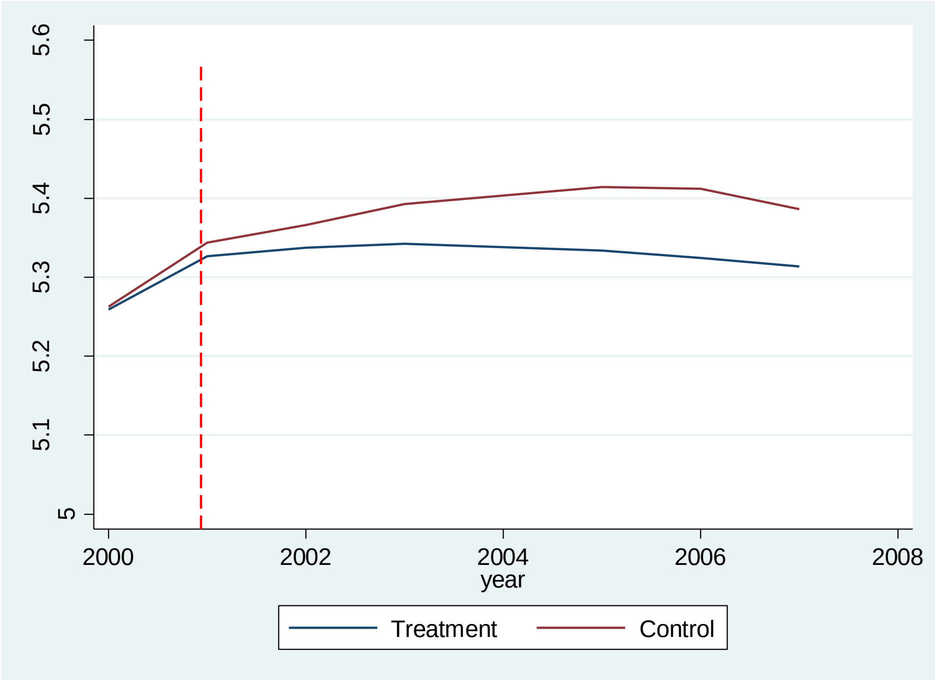

Figure 6: Trends of labor demand over time

In addition, we also conduct pre-treatment test for SO_2 emissions and labor demand. One way to check the identification assumption is to examine whether the assumption is satisfied several years before the policy. The corresponding regression specification is as follow:

$$Y_{it} = \alpha_i + \gamma_t + \eta_{jt} + \omega_{rt} + \beta_1 KEPC_i \times Post2001_t + \sum_{s\geq 1} \delta_s \cdot KEPC_i \times \lambda_{2002-s} + \varepsilon_{it} \qquad (6)$$

Where δ_s represents the pre-treatment effect. If $\delta_s = 0 \forall s \geq 1$, the assumption in our setting is satisfied. λ_{2002-s} refer to a set of year dummies prior the policy year. Y_{it} refer to log of SO_2 emissions or log of labor demand. The meaning of other coefficients and variables are consistent with equation (1).

The results of the pre-treatment test corresponding to equation (6) are showed in Table 3 and Table 4. In column (1), we control year fixed effects and enterprise fixed effects, and in column (2), we further control year-industry and year-region fixed effects. KEPC*Year2001 (an indicator of one year before the policy) has any statistical significance for both SO_2 emission and labor demand. The results indicate that the treated and non-treated groups have similar time trend (at least) one year before the treatment, which implies that SO_2 emission and labor demand of treated group may follow the same trend as the non-treated group in the case of no policy.

Table 3 Pre-treatment test on SO_2

	(1)	(2)
	ln(SO2)	ln(SO2)
	FE	FE
KEPC*Post2001	-0.154**	-0.163**
	(0.0734)	(0.0766)
KEPC*Year2001	0.0240	0.0108
	(0.0713)	(0.0722)
Year fixed effects	YES	YES
Enterprise fixed effects	YES	YES
Year-industry fixed effects		YES
Year-region fixed effects		YES
Constant	10.28***	10.53***
	(0.0301)	(0.317)
Observations	10904	10904
R-squared	0.814	0.820

(Robust-Clustered Standard Errors)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Pre-treatment test on Labor

	(1)	(2)
	ln(Labor)	ln(Labor)
	FE	FE
KEPC*Post2001	-0.0663***	-0.0305**
	(0.0133)	(0.0137)
KEPC*Year2001	-0.0141	0.00433
	(0.00990)	(0.0103)
Year fixed effects	YES	YES
Enterprise fixed effects	YES	YES
Year-industry fixed effects		YES
Year-region fixed effects		YES
Constant	5.261***	5.200***
	(0.00543)	(0.0678)
Observations	87512	87512
R-squared	0.890	0.893

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

6.2 Main SO_2 Emission Results

Our DID results on SO_2 emission corresponding to equation (1) are reported in Table 5. For all models we use robust, cluster (enterprise level) standard errors to construct our confidence intervals. Column 1 shows our most basic OLS results. In column 2 we drop the year fixed effects and add in a quadratic time trend, so we can identify the coefficient on Post2001. In columns 3 we also include industry fixed effects and region fixed effects, since each industry has a unique production process and differences between regions are large in China. In columns 4-6 we present our preferred specifications which include enterprise fixed effects to control for any omitted time invariant effects[27]. The results are indicate that SO_2 emissions are, on average, significantly higher for KEPC enterprises than enterprises in control group for our entire sample period, which is consistent with Figure 3 and Figure 5, but SO2 emissions are not significantly different during the policy period (Post2001) relative to the pre-policy period. However, the estimates on KEPC*Post2001 our main variable of interest are significantly negative in all six models implying that, after the policy change, manufacturing enterprises in the KEPC facing the tougher environmental requirement significantly decreased SO_2 emissions relative to the manufacturing enterprises in matched control groups. These results provide evidence that the new environmental regulation is effective in terms of reducing SO_2 emissions. The point estimates from our preferred specifications suggest that SO_2 emissions declined by 15%.

Although the 113 KEPCs were assigned mainly based on air quality situations, after the designation, requirements were extended to reaching water environmental quality as well, so we also conduct a test by examining its impact on COD discharges. As the results showed in Table 6, the estimates on KEPC*Post2001 our main variable of interest are insignificant in all six models implying that, the new environmental regulation is ineffective in terms of reducing COD discharges. A possible reason is that compared to air quality requirements, water quality requirements are relatively vague.

[27] All tables below follow a similar format.

Table 5 DID results on SO_2 emission

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.166***	-0.166***	-0.190***	-0.166***	-0.165***	-0.168***
	(0.0533)	(0.0533)	(0.0544)	(0.0569)	(0.0569)	(0.0594)
KEPC	0.186*	0.186*	0.0565			
	(0.101)	(0.100)	(0.0975)			
Post2001		-0.0177			-0.0181	
		(0.0463)			(0.0494)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0709***			0.0709**	
		(0.0258)			(0.0276)	
Time trend squared		-0.00658**			-0.00658**	
		(0.00293)			(0.00314)	
Constant	10.20***	10.20***	9.207***	10.28***	10.28***	10.53***
	(0.0692)	(0.0678)	(0.339)	(0.0301)	(0.0275)	(0.317)
Observations	10904	10904	10904	10904	10904	10904
R-squared	0.001	0.001	0.161	0.814	0.813	0.820

(Robust-Clustered Standard Errors)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6 DID results on COD discharges

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(COD)	ln(COD)	ln(COD)	ln(COD)	ln(COD)	ln(COD)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.107	-0.109	-0.134	-0.116	-0.117	-0.176
	(0.122)	(0.122)	(0.122)	(0.130)	(0.130)	(0.135)
KEPC	-0.198	-0.198	0.197			
	(0.250)	(0.250)	(0.208)			
Post2001		0.246**			0.0640	
		(0.0995)			(0.105)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		-0.218***			0.135**	
		(0.0589)			(0.0573)	
Time trend squared		0.0724***			0.000251	
		(0.00762)			(0.00661)	
Constant	6.726***	6.922***	5.884***	6.906***	6.962***	7.086***
	(0.167)	(0.162)	(0.659)	(0.0664)	(0.0608)	(0.700)
Observations	10374	10374	10374	10374	10374	10374
R-squared	0.033	0.030	0.344	0.832	0.832	0.841

(Robust-Clustered Standard Errors)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.3 Main Employment Results

The DID results for the effect of the new environmental regulation on employment, our main outcome of interest, are reported in Table 7. Also we use robust, cluster (enterprise level) standard errors to construct our confidence intervals. The results indicate that employment is, on average, similar for KPEC enterprises relative to matched control group enterprises[28], which is consistent with figure 4. Moreover, employment is higher for all enterprises in the policy period (Post2001) relative to the pre-policy period. The estimates on KEPC*Post2001, our main variable of interest, are all significantly negative implying that, after the policy change, manufacturing enterprises in the KEPC, facing the tougher environmental regulation, employed significantly less workers than enterprises in the matched control group. These results provide evidence that the new environmental regulation has led to significantly lower levels of employment in the manufacturing sector in the KEPCs. The point estimates, in our preferred models with enterprise fixed effects, suggest that employment fell by 3-6% relative to compared enterprises in the non-KEPCs.

[28] While if we control industry fixed effects and region fixed effects, enterprises in KEPC have less employment compared to matched control group enterprises in same region and same industry.

Table 7 DID results on Labor demand

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.0593***	-0.0593***	-0.0579***	-0.0593***	-0.0593***	-0.0327***
	(0.00999)	(0.00999)	(0.0102)	(0.0107)	(0.0107)	(0.0110)
KEPC	-0.0115	-0.0115	-0.0634***			
	(0.0208)	(0.0208)	(0.0205)			
Post2001		0.0157**			0.0157**	
		(0.00655)			(0.00700)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0461***			0.0461***	
		(0.00350)			(0.00374)	
Time trend squared		-0.00490***			-0.00490***	
		(0.000376)			(0.000402)	
Constant	5.266***	5.283***	4.821***	5.261***	5.277***	5.200***
	(0.0144)	(0.0143)	(0.0638)	(0.00543)	(0.00520)	(0.0678)
Observations	87512	87512	87512	87512	87512	87512
R-squared	0.002	0.002	0.066	0.890	0.890	0.893

(Robust-Clustered Standard Errors)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.4 Heterogeneity Analyses

In this section we investigate whether or not the KEPC policy has a differential effect on employment by enterprise ownership type (state-owned, domestic private, and foreign private), industry (2-digit National Standard Industrial Classification industries), and firm age (old or young).

We first examine whether or not there are heterogeneous employment effects by ownership type. According to previous research, in contrast to private enterprises, state-owned enterprises are not necessarily cost minimizing. In fact, state-owned enterprises have long been considered an ‘iron rice bowl’ in China, where workers are pretty much assured of a job as long as they want it – it is very difficult for state-owned enterprise to dismiss workers. Therefore we expect that the new wastewater discharge standard will not have a significant impact on employment in state-owned enterprises. On the other hand, foreign enterprises are known to have better environmental performance than domestically privately owned enterprises and thus they may not need to do as much to comply with the environmental regulation as either state-owned or domestically-private owned enterprises (Dean, Lovely et al. 2009). Therefore, we expect the KEPC policy to have a more substantial impact on domestic privately owned enterprises relative to foreign owned enterprises. The results in Table 8 and Table 9 indicate that the KEPC policy has the expected significant, negative effects on the SO_2 emissions (-15%) at domestic private and state-owned enterprises and employment (-3%) at domestic private enterprises only. On the other hand, the KEPC policy does not have any significant impact on SO_2 emissions or employment at foreign enterprises. Thus, our results indicate that domestic private enterprises, who often do not have ‘home-field’ advantage in China, are the more affected by the KEPC policy than their state and foreign owned counterparts.

Table 8 DID results on SO_2 emission by ownerships

	(1)	(2)	(3)
	ln(SO2)	ln(SO2)	ln(SO2)
	State-owned	Private	Foreign
	FE	FE	FE
KEPC*Post2001	-0.159*	-0.164**	-0.428
	(0.0964)	(0.0792)	(0.283)
Year fixed effects	YES	YES	YES
Enterprise fixed effects	YES	YES	YES
Year-industry fixed effects	YES	YES	YES
Year-region fixed effects	YES	YES	YES
Constant	11.49***	10.74***	10.19***
	(0.584)	(0.293)	(0.176)
Observations	3608	6176	784
R-squared	0.874	0.800	0.816

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 9 DID results on Labor demand by ownerships

	(1)	(2)	(3)
	ln(Labor)	ln(Labor)	ln(Labor)
	State-owned	Private	Foreign
	FE	FE	FE
KEPC*Post2001	-0.00662	-0.0296*	0.00275
	(0.0199)	(0.0158)	(0.0275)
Year fixed effects	YES	YES	YES
Enterprise fixed effects	YES	YES	YES
Year-industry fixed effects	YES	YES	YES
Year-region fixed effects	YES	YES	YES
Constant	5.546***	5.060***	4.961***
	(0.130)	(0.0844)	(0.149)
Observations	17632	51082	18798
R-squared	0.939	0.895	0.902

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

We then do the heterogeneity analyses by industries. The production processes in different industries are very different, so we now examine whether or not the KEPC policy had a larger impact on enterprises in some specific industries compared to others. To do this we divide the sample into different industries according to the 2-digit National Standard Industrial Classification. The results in Table 10 indicate that the impact of the KEPC policy on labor demand[29] show significant heterogeneity among industries. Artworks & Other Products Manufacturing (-21%), Communications Equipment, Computer & Other Electric Equipment Manufacturing (-19%), Metal Products (-17%), Printing & Record Medium Reproduction (-16%), Transport Equipment (-11%), Papermaking & Paper Products (-9%), Plastic Products (-9%) and General Machinery Manufacturing (-7%) were more or less negatively affected by the KEPC policy in terms of labor demand. Most others were not affected by the KEPC policy, such as Major Grain & Sideline Food Processing, Food Production, Beverage Production and et al. While, Timber, Bamboo, Cane, Palm Fiber, Straw Products (17%) and Medical & Pharmaceutical Products (13%) were positively affected by the KEPC policy in terms of labor demand. There are two main mechanisms behind the different effects – the level of exposure to the KEPC policy varies across industries and the elasticity of demand also varies across industries.

[29] We also wanted to check the heterogeneity effects on SO2 emission, but the sample size are too small in CESD to do the grouping analysis.

Table 10 DID results on Labor demand by industries

Industry code	Industry name	ln(Labor)
13	Major Grain & Sideline Food Processing	-0.00198
14	Food Production	-0.0878
15	Beverage Production	0.00153
16	Tobacco Processing	0.0749
17	Textile Industry	-0.0447
18	Textile Clothes, Shoes & Caps Producing	-0.0181
19	Leathers, Furs, Down & Related Products	0.0389
20	**Timber, Bamboo, Cane, Palm Fiber, Straw Products**	**0.153***
21	Furniture Manufacturing	-0.195
22	**Papermaking & Paper Products**	**-0.0968***
23	**Printing & Record Medium Reproduction**	**-0.171****
24	Culture, Education & Sports Facilities Producing	-0.191*
25	Petroleum Processing, Coking Products & Nuclear Fuel Processing	0.0325
26	Raw Chemical Materials & Chemical Products	-0.0263
27	**Medical & Pharmaceutical Products**	**0.123****
28	Chemical Fiber	0.183
29	Rubber Products	-0.123
30	**Plastic Products**	**-0.0910***
31	Nonmetal Mineral Products	0.0356
32	Smelting & Pressing of Ferrous Metals	-0.00581
33	Smelting & Pressing of Nonferrous Metals	-0.0902
34	**Metal Products**	**-0.183*****
35	**General Machinery Manufacturing**	**-0.0773***
36	Special Purpose Equipment	-0.0503
37	**Transport Equipment**	**-0.122****
39	Electric Equipment & Machinery Manufacturing	0.00385
40	**Communications Equipment, Computer & Other Electric Equipment Manufacturing**	**-0.205*****
41	Instruments, Meters, Cultural & Clerical Machinery	-0.107
42	**Artworks & Other Products Manufacturing**	**-0.236***

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Another important factor influencing the impact of environmental regulation on labor demand is age. Gray et al. (2014) argue that older enterprises may have higher pollution levels and thus may face greater regulatory scrutiny. Moreover, older plants may also have different labor demand and elasticity of substitution among factors of production and could have changed employment levels differently from less regulated plants over time. So we use statistical year minus opening year to calculate age and divide sample into two groups (old and young[30]) according to age. As is showed in Table 12, only old enterprises were affected by the KEPC policy (-3%) which is consistent with existing literature (Gray et al. 2014).

Table 12 DID results on Labor demand by age

	(1) ln(Labor) Old FE	(2) ln(Labor) Young FE
KEPC*Post2001	-0.0346**	-0.000593
	(0.0148)	(0.0156)
Year fixed effects	YES	YES
Enterprise fixed effects	YES	YES
Year-industry fixed effects	YES	YES
Year-region fixed effects	YES	YES
Constant	5.462***	5.049***
	(0.106)	(0.0942)
Observations	39040	48456
R-squared	0.914	0.873

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

[30] Enterprises had been built more than 8 years in 2000 are defined old, otherwise young.

7. Robustness checks

In this section, we conduct a series of additional robustness checks on our results. First, we change the condition to only exclude enterprises whose SO_2 emissions were 0 for all the years during 2000-2007 as a robustness check. Table 13 shows the results using the same specifications with Table 5. The estimates on KEPC*Post2001 our main variable of interest are significantly negative in all six models, which is same with our baseline results. The point estimates from our preferred specifications suggest that SO_2 emissions declined by 27%. Second, in order to consider differences between regions, we change our matching strategy to restrict the treated city and the matched city being from a same region. Given the big differences among China, we then divide the whole country into four regions according to the geographical divisions of the country, i.e., northeastern region, eastern region, central region and western region. Table 14 and Table 15 show the results for SO_2 emissions and labor demand using alternative PSM strategy[31]. The estimates on KEPC*Post2001 our main variable of interest are significantly negative in all six models, which is same with our baseline results. The point estimates from our preferred specifications suggest that SO_2 emissions declined by 20% and labor demand declined by 8%.Third, since the data for 2004 are from a different source - economic census which has a larger investigation scope than others, we drop data in 2004 for the labor analysis in case there are inconsistencies over the years. The results in Table 16 indicate that the impact of the KEPC policy on labor demand are still significant (-3%) even though we drop data for 2004. Finally, we also drop enterprises of the top 10% and bottom 10% output values. The results in Table 17 show that the estimates on KEPC*Post2001 our main variable of interest are significantly negative in all six models, which is same with our baseline results but show larger effects on labor demand than our baseline results.

[31] We also conduct a pre-treatment check before DID regression. KEPC*Year2001 (an indicator of one year before the policy) has any statistical significance for both SO2 emission and labor demand.

Table 13 Robustness check: include SO_2 0 values

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.320***	-0.320***	-0.329***	-0.319***	-0.319***	-0.314***
	(0.0867)	(0.0867)	(0.0880)	(0.0925)	(0.0924)	(0.0998)
KEPC	0.572***	0.572***	0.272**			
	(0.135)	(0.135)	(0.123)			
Post2001		0.128*			0.127	
		(0.0742)			(0.0792)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0164			0.0165	
		(0.0415)			(0.0443)	
Time trend squared		0.00276			0.00276	
		(0.00469)			(0.00501)	
Constant	9.440***	9.490***	8.678***	9.682***	9.731***	9.792***
	(0.103)	(0.100)	(0.407)	(0.0510)	(0.0465)	(0.449)
Observations	12320	12320	12320	12320	12320	12320
R-squared	0.005	0.005	0.222	0.737	0.737	0.749

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 14 Robustness check: DID results on SO_2 emissions using alternative PSM strategy

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)	ln(SO2)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.220***	-0.220***	-0.241***	-0.220***	-0.220***	-0.226***
	(0.0637)	(0.0636)	(0.0659)	(0.0681)	(0.0680)	(0.0724)
KEPC	0.286**	0.286**	0.188			
	(0.120)	(0.120)	(0.115)			
Post2001		-0.0348			-0.0348	
		(0.0531)			(0.0567)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.103***			0.103***	
		(0.0306)			(0.0327)	
Time trend squared		-0.0119***			-0.0119***	
		(0.00359)			(0.00384)	
Constant	10.20***	10.19***	9.865***	10.33***	10.32***	10.64***
	(0.0833)	(0.0819)	(0.478)	(0.0362)	(0.0327)	(0.354)
Observations	6904	6904	6904	6904	6904	6904
R-squared	0.002	0.002	0.178	0.799	0.798	0.809

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 15 Robustness check: DID results on Labor demand using alternative PSM strategy

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.0869***	-0.0868***	-0.0857***	-0.0862***	-0.0862***	-0.0797***
	(0.0112)	(0.0112)	(0.0114)	(0.0120)	(0.0120)	(0.0120)
KEPC	-0.0861***	-0.0861***	-0.0926***			
	(0.0231)	(0.0231)	(0.0227)			
Post2001		0.0279***			0.0277***	
		(0.00739)			(0.00790)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0559***			0.0557***	
		(0.00390)			(0.00416)	
Time trend squared		-0.00560***			-0.00557***	
		(0.000416)			(0.000445)	
Constant	5.245***	5.264***	4.720***	5.203***	5.222***	5.105***
	(0.0168)	(0.0166)	(0.110)	(0.00618)	(0.00585)	(0.0965)
Observations	67928	67928	67928	67928	67928	67928
R-squared	0.007	0.006	0.085	0.893	0.893	0.896

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 16 Robustness check: DID results on Labor demand (without 2004 data)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.0532***	-0.0532***	-0.0522***	-0.0530***	-0.0530***	-0.0264**
	(0.00995)	(0.00995)	(0.0101)	(0.0107)	(0.0107)	(0.0110)
KEPC	-0.0107	-0.0107	-0.0638***			
	(0.0208)	(0.0208)	(0.0205)			
Post2001		0.00232			0.00220	
		(0.00656)			(0.00708)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0615***			0.0613***	
		(0.00355)			(0.00383)	
Time trend squared		-0.00680***			-0.00677***	
		(0.000390)			(0.000420)	
Constant	5.266***	5.276***	4.831***	5.262***	5.271***	5.212***
	(0.0144)	(0.0143)	(0.0631)	(0.00531)	(0.00501)	(0.0761)
Observations	76899	76899	76899	76899	76899	76899
R-squared	0.002	0.002	0.066	0.888	0.888	0.891

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 17 Robustness check: DID results on Labor demand (without max and min values)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)	ln(Labor)
	OLS	OLS	OLS	FE	FE	FE
KEPC*Post2001	-0.122***	-0.122***	-0.122***	-0.108***	-0.108***	-0.0425***
	(0.0110)	(0.0110)	(0.0112)	(0.0109)	(0.0109)	(0.0118)
KEPC	0.122***	0.122***	0.0724***			
	(0.0221)	(0.0221)	(0.0229)			
Post2001		0.0200***			0.0113*	
		(0.00634)			(0.00624)	
Year fixed effects	YES		YES	YES		YES
Enterprise fixed effects				YES	YES	YES
Industry fixed effects			YES			
Region fixed effects			YES			
Year-industry fixed effects						YES
Year-region fixed effects						YES
Time trend		0.0583***			0.0644***	
		(0.00382)			(0.00379)	
Time trend squared		-0.00651***			-0.00622***	
		(0.000412)			(0.000403)	
Constant	5.281***	5.293***	4.860***	5.304***	5.313***	5.250***
	(0.0132)	(0.0131)	(0.0704)	(0.00550)	(0.00521)	(0.0705)
Observations	84405	84405	84405	84405	84405	84405
R-squared	0.002	0.002	0.076	0.890	0.890	0.893

(Robust-Clustered Standard Errors)

* p < 0.1, ** p < 0.05, *** p < 0.01

8. Conclusions

The main contribution of this paper is our use of enterprise-level data from a developing country – China, a country which has historically been focused on economic growth, but now which is also concerned environmental quality – to examine the impact of environmental regulation on labor demand. In this paper, we estimated the employment impacts of KEPC policy. We adopt a robust DID approach with PSM approach, including enterprise fixed effects, to control for the potential endogeneity of environmental regulations.

Our results suggest that the KEPC policy effectively lowered SO_2 emissions. Manufacturing enterprises facing the tougher environmental regulation decreased their SO_2 emissions by roughly 15% relative to non-treated enterprises in the matched control group. More importantly, the new environmental regulation significantly reduced labor demand, but the impacts were relatively small, on the order of 3-6%. Furthermore, we found heterogeneous impacts of the new regulation by type of enterprise ownership, age and industry. More specifically, we found that the more stringent discharge standard has greater negative effects on employment in domestic privately owned enterprises and old enterprises. As China continues to strengthen its environmental regulations the potential negative impacts on employment should be carefully considered when analyzing the economic impacts of environmental regulations and planning for sustainable economic growth. China is on the process of solving the overcapacity and air pollution through a series of supply-side reform such as closing some steel companies, which may bring larger impact on unemployment.

Our research complements existing studies that focus more or less exclusively on developed economies, but there is still more work to be done in the developing economy context, so we plan to extend our work in several ways. First, we will examine the effect of environmental regulation on employment via its impact on induced exit of enterprises and dissuaded entry. We will also broaden our study to examine the effect of environmental regulation on labor demand at the regional and industry level as well. Second, we will examine the employment effects associated with different pollution reduction activities. Third, to identify which types of workers may be more vulnerable to environmental regulation we will examine the effect of environmental regulation on the demand for different types of workers (e.g. experienced and non-experienced workers, skilled and unskilled workers, highly educated and less educated).

References

Abrell, J., A. Ndoye Faye and G. Zachmann (2011). "Assessing the impact of the EU ETS using firm level data." Bruegel working paper.Alford, W. P. (1997). "Law, Law, What Law?: Why Western Scholars of Chinese History and Society Have Not Had More to Say about Its Law." Modern China: 398-419.

Anger, N. and U. Oberndorfer (2008). "Firm performance and employment in the EU emissions trading scheme: An empirical assessment for Germany." Energy policy 36(1): 12-22.

Berman, E. and L. T. Bui (2001). "Environmental regulation and labor demand: Evidence from the south coast air basin." Journal of Public Economics 79(2): 265-295.

Bovenberg, A. L. and F. van der Ploeg (1996). "Optimal taxation, public goods and environmental policy with involuntary unemployment." Journal of Public Economics 62(1): 59-83.

Brandt, L., J. Van Biesebroeck and Y. Zhang (2012). "Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing." Journal of Development Economics 97(2): 339-351.

Chan, H. S. R., S. Li and F. Zhang (2013). "Firm competitiveness and the European Union emissions trading scheme." Energy Policy 63: 1056-1064.

Chen, Y., A. Ebenstein, M. Greenstone and H. Li (2013). "Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy." Proceedings of the National Academy of Sciences 110(32): 12936-12941

Cole, M. A. and R. J. Elliott (2007). "Do environmental regulations cost jobs? An industry-level analysis of the UK." The BE Journal of Economic Analysis & Policy 7(1).

Crane, K. and Z. Mao (2015). "Costs of Selected Policies to Address Air Pollution in China."

Dean, J. M., M. E. Lovely and H. Wang (2009). "Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China." Journal of Development Economics 90(1): 1-13.

Ferris, A. E., R. J. Shadbegian and A. Wolverton (2014). "The Effect of Environmental Regulation on Power Sector Employment: Phase I of the Title IV SO2 Trading Program." Journal of the Association of Environmental and Resource Economists 1(4): 521-553.

Gray, W. B. and R. J. Shadbegian (2014). "Do the job effects of regulation differ with the competitive environment?" Does Regulation Kill Jobs?, edited by Cary Coglianese, Adam Finkel & Chris Carrigan. University of Pennsylvania Press.

Gray, W. B., R. J. Shadbegian, C. Wang and M. Meral (2014). " Do EPA regulations affect labor demand? Evidence from the pulp and paper industry. "Journal of Environmental Economics and Management, 68(1), 188-202.

Greenstone, M. (2002). "The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 clean air act amendments and the census of manufactures." Journal of Political Economy 110(6): 1175-1219.

Hsieh, Chang-Tai and Klenow, Peter J. (2009) "Misallocation and Manufacturing TFP in China and India." Quarterly Journal of Economics 124: 1403-1448.

Kahn, M. E., P. Li and D. Zhao (2015). "Water Pollution Progress at Borders: The Role of Changes in China's Political Promotion Incentives." American Economic Journal: Economic Policy 7(4): 223-242.

Ma, C. (2010). "Who bears the environmental burden in China—An analysis of the distribution of industrial pollution sources?" Ecological Economics 69(9): 1869-1876.

Morgenstern, R. D., W. A. Pizer and J.-S. Shih (2002). "Jobs versus the environment: an industry-level perspective." Journal of Environmental Economics and Management 43(3): 412-436.

Rosenbaum, P.R., Rubin, D.B. (1983). "The central role of the propensity score in observational studies for causal effects." Biometrika 70(1): 41-55.

Vennemo, H., K. Aunan, H. Lindhjem and H. M. Seip (2009). "Environmental pollution in China: status and trends." Review of Environmental Economics and Policy 3(2): 209-230.

Walker, W. R. (2013). "The Transitional Costs of Sectoral Reallocation: Evidence From the Clean Air Act and the Workforce." The Quarterly Journal of Economics 128(4): 1787-1835.

Walker, W. R. (2011). "Environmental regulation and labor reallocation: Evidence from the Clean Air Act." The American Economic Review 101(3): 442-447.

Wang, H. and D. Wheeler (2005). "Financial incentives and endogenous enforcement in China's pollution levy system." Journal of Environmental Economics and Management 49(1): 174-196.

Wang, H., N. Mamingi, B. Laplante and S. Dasgupta (2003). "Incomplete enforcement of pollution regulation: Bargaining power of Chinese factories." Environmental and Resource Economics 24(3): 245-262.

Wu, H., H. Guo, B. Zhang and M. Bu (2016). "Westward Movement of New Polluting Firms in China: Pollution Reduction Mandates and Location Choice." Journal of Comparative Economics (forthcoming).

Appendix A

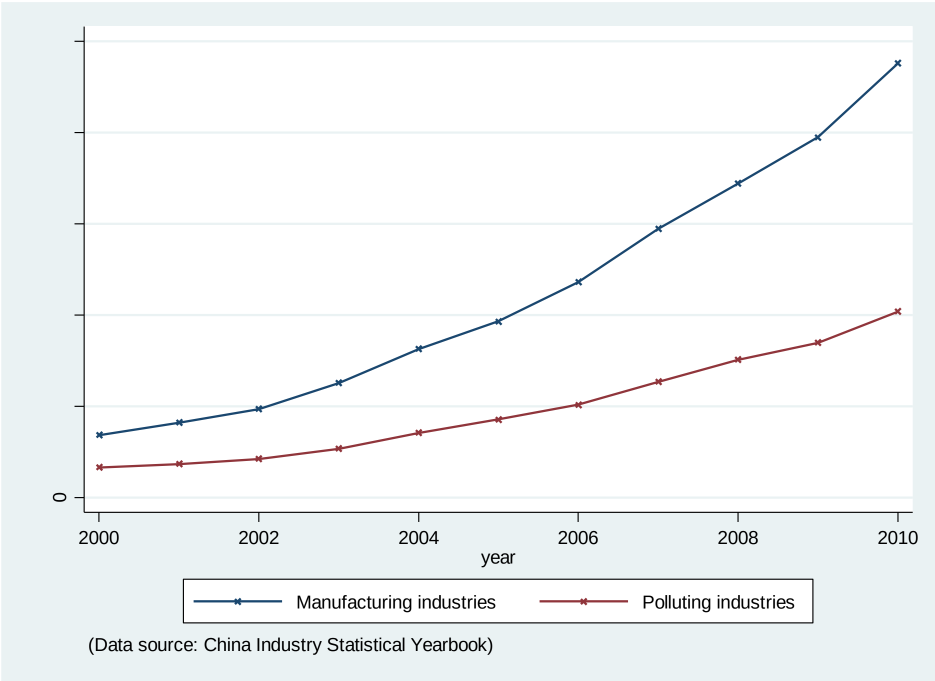

Figure A1: Output of manufacturing industries and Top 10 polluting industries

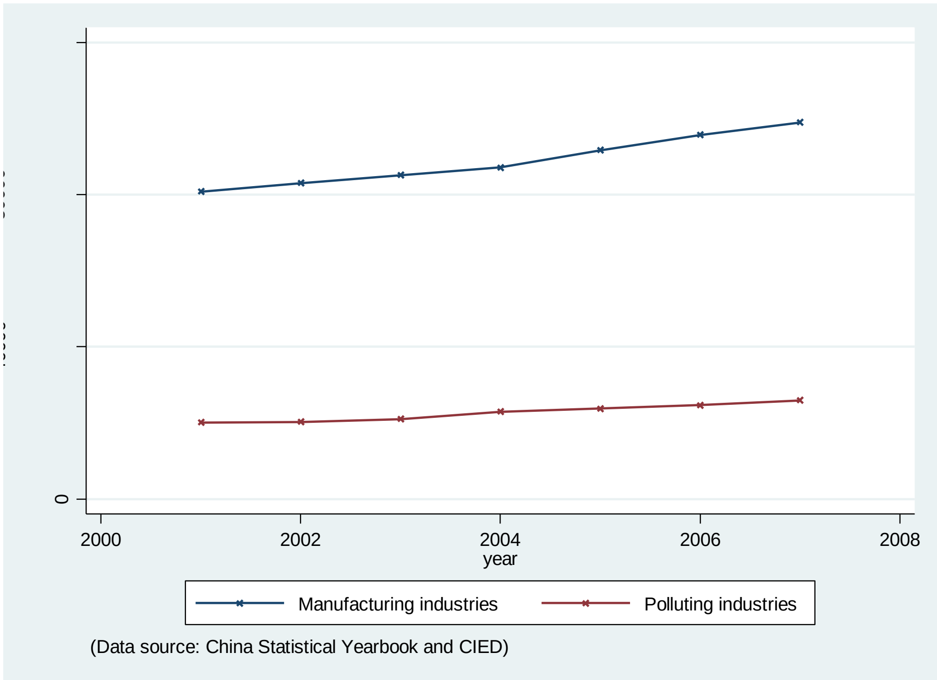

Figure A2: Employment of manufacturing industries and Top 10 polluting industries

Appendix B

List of 113 Key Environmental Protection Cities

First batch		Second batch	
4505	1401	2103	2302
1100	1200	4105	5303
2201	3303	1502	3505
4301	6501	1306	3711
5101	4201	6103	4112
2102	6101	2105	4402
3501	6301	4307	3306
4401	3502	3204	6402
4503	3706	1404	3709
5201	6401	4310	1302
2301	4408	1504	6102
4601	4101	1402	3707
3301	5000	5106	6105
3401	4404	2104	3202
1501		1304	3402
3701		3305	6104
5301		2202	4303
5401		3708	3203
6201		4108	6106
3207		6203	3210
3601		2107	1403
3201		4210	5115
4501		3604	4205
3206		4102	5304
3302		6502	4306
1303		1410	3704
3702		4103	4308
4405		3405	3211
3100		5107	4302
4403		2310	3703
2101		5113	5103
1301		5104	5203
3205		4104	5105

Appendix C

List of TCZ cities

Acid rain		SO2			
3100	3604	4401	5106	1406	3714
3201	3606	4403	5109	1409	4101
3210	3610	4404	5110	1407	4103
3206	3608	4405	5111	1410	4108
3211	3607	4402	5113	1408	4105
3204	4201	4413	5115	1501	4112
3202	4202	4415	5116	1502	4190
3205	4210	4419	5114	1503	6101
3212	4205	4420	5201	1504	6102
3301	4208	4407	5203	2101	6105
3302	4207	4406	5204	2102	6110
3303	4212	4408	5223	2103	6201
3304	4301	4412	5226	2104	6203
3305	4302	4453	5227	2105	6204
3306	4303	4418	5301	2107	6207
3307	4304	4451	5303	2114	6401
3308	4306	4452	5304	2109	6402
3310	4307	4501	5306	2110	6501
3402	4308	4513	5325	2202	
3407	4310	4503	1101	2203	
3405	4309	4509	1201	2205	
3410	4313	4508	1301	2224	
3414	4312	4514	1304	3203	
3414		4502	1305	3701	
3501		4503	1306	3702	
3502		4511	1307	3703	
3504		4512	1308	3704	
3505		5000	1302	3707	
3506		5101	1311	3706	
3508		5103	1401	3708	
3601		5104	1402	3709	
3603		5105	1403	3712	

Appendix D

List of NFHCC

Tianjin	Shouxian	Quanzhou
Baoding	Bozhou	Jingdezhen
Jinan	Fuzhou	Qufu
Anyang	Zhangzhou	Luoyang
Nanyang	Nanchang	Kaifeng
Shangqiu	Beijing	Jingzhou
Wuhan	Chengde	Changsha
Xiangyang	Datong	Guangzhou
Chaozhou	Nanjing	Guilin
Chongqing	Suzhou	Chengdu
Langzhong	Yangzhou	Yueyang
Yibin	Changting	Zhaoqing
Zigong	Ganzhou	Foshan
Zhenyuan	Qingdao	Meizhou
Lijiang	Liaocheng	Leizhou
Rikaze	Zoucheng	Liucheng
Hancheng	Zibo	Qiongshan
Yulin	Zhengzhou	Leshan
Wuwei	Junxian	Dujiangyan
Zhangye	Suizhou	Luzhou
Dunhuang	Zhongxiang	Zunyi
Yinchuan	Zhengding	Kunming
Kashi	Handan	Dali
Hohehot	Xinjiang	Lasa
Shanghai	Daixian	Xian
Xuzhou	Qixian	Yanan
Pingyao	Harbin	Jianshui
Shenyang	Jilin	Weishan
Zhenjiang	Jian	Jiangzi
Changshu	Quzhou	Xianyang
Huaian	Linhai	Hanzhong
Ningbo	Hangzhou	Tianshui
Hexian	Shaoxing	Tongren