Are Environmental Punishments Good News or Bad News? Evidence from China

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Abstract: This paper exploits the information disclosure and dissemination of environmental punishments on housing prices. As environmental quality is hardly ameliorated in the short run, the environmental punishments normally convey bad news of environmental quality rather than good news to housing market. The information disclosure of environmental punishment adds new pollution source information to the public. Employing the micro databases of firm-level environmental punishments and housing resale transactions in Beijing from January 2015 to December 2017, this research reveals that the transaction prices of houses within 0.5 kilometers distance from the environmentally punished firms decrease by 1.84% on average and the overlapping effects of environmental punishments are fortified by multiple environmental punishments. In addition, the negative effects are amplified in the heating seasons and in the national important events. Unfortunately, we find little evidence of environmental punishments in the rental housing market. This paper identifies three mechanisms of environmental punishments on housing prices. The first mechanism is information disclosure, which proves that the impacts of environmental punishments on housing prices magnify if the information of environmental punishments is released to the public and reinforce with environmental information searching. The second mechanism is information dissemination, which corroborates that the negative effects of environmental punishments on housing transaction prices decay with distance and over time. The third mechanism is health concern arising from environmental punishments, which documents that relative to the unmarried young homebuyers, the older homebuyers and homebuyers with children have stronger responses to the environmental punishments.

Key words: Environmental Punishments, Housing Transaction Prices, Information Disclosure, Information Dissemination, Health Concern

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1. Introduction

Environmental regulations are widely adopted to ameliorate environmental quality, particularly in developing countries with extreme environmental pollution like China and India (Chay & Greenstone, 2005; Greenstone & Hana, 2014; Keiser & Shapiro, 2019; He et al., 2020). On the other hand, environmental regulations could result in non-negligible economic aftermaths. Environmental regulations increase production cost and unemployment (Greenstone, 2002; Walker, 2011, 2013; Ryan, 2012; Viard & Fu, 2015; Agarwal et al., 2019), and decrease total factor productivity and outputs of pollution-intensive industries (Greenstone, 2002; He et al., 2020). Nevertheless, as to information disclosure of environmental regulation, the prior literature concentrate on how environmental information disclosure affects the reactions and consequences of polluting firms, but neglects how information disclosure influences the responses and outcomes of market participants (e.g. investors and consumers). The most related literature of environmental information disclosure to this research involves in two kinds of previous studies. The first stand of extant literature investigates the motives and consequences of environmental information disclosure (Konar & Cohen, 1997; Zeng et al., 2010; Kim & Lyon, 2011; Meng et al., 2013). They discover that the nature of a firm affects the level of environmental information disclosure (Zeng et al., 2010), while the level of environmental information disclosure is determined by strategic motives, performance and legitimacy impressions of firms (Kim & Lyon, 2011; Meng et al., 2013). Konar & Cohen (1997) take information as quasi-regulatory mechanism and find that mandatory disclosure requirements substantially reduced firm toxic emissions. The second strand of preceding works examine the efficacy of environmental enforcement on polluting firms (Shimshack & Ward, 2005, 2008; He et al., 2020). Shimshack & Ward (2005) find that water pollution enforcement on a sanctioned plant can spillover into environmental compliance of the other plants. Shimshack & Ward (2008) further documents that the increased water pollution enforcement could give rise to over-compliance of the sanctioned and non-sanctioned plants. In terms of political incentive theory, He et al. (2020) document that China's water quality monitoring system substantially reduces the total factor productivity (TFP) of the polluting firms and engender a sizable social economic cost. Hence, the prior studies mainly focus on the impacts of environmental enforcement on environment pollution producers/suppliers. In contrast to the conventional wisdom, from the angle of market participants, this research focuses on the influences of environmental enforcement information disclosure and dissemination on homebuyers and housing prices, and fill in the gap to exploit how environmental enforcement information affects homebuyers' behavior and housing prices.

The related housing literature has identified two contrasting effects of environmental law enforcement on housing prices. A body of literature find that environmental regulations increase housing price due to the decline in pollutant concentration (Kim et al., 2003; Chay & Greenstone, 2005; Bayer et al., 2009; Luechinger, 2009; Zheng et al., 2010; Davis, 2011; Bajari et al., 2012; Currie et al., 2015; Bayer et al., 2016; Agarwal et al., 2019; Lavaine, 2019). By contrast, another body of literature finds that environmental regulations decrease housing prices by virtue of the decline in local employments and economic outputs (Agarwal et al., 2019). It deserves noting that the previous studies normally take the release of environmental regulations as external shocks and utilize difference-in-differences method to testify the effects of environmental regulations on

housing prices. Unfortunately, the extant literature fails to investigate the market responses to the information disclosure of environmental enforcement. In essence, the pollution source is hard for the public to observe unless the pollution information is publicly disclosed. The environmental punishments could not fundamentally alter air quality in the short run, particularly in the countries with weak institutions (Auffhammer & Maximilian, 2011; Duflo et al., 2013). As a consequence, information disclosure and dissemination of environmental punishments predominantly convey bad news of environmental quality to the housing market in the short term. Once a punished firm was disclosed to the public, the homebuyers around the punished firms normally regard the environmental punishments as serious pollution signals, which retards housing investment and reduce housing prices. In addition, the polluting firms have smaller impacts on the houses which are far from them because the pollutants emitted from the polluting firms dilute and dissipate with distance (Currie et al., 2015; Mei et al., 2021). Likewise, environmental punishment information dissipates over time in the sense that homebuyers' attention is becoming weakening and simultaneously environmental quality is gradually improving over time (Figlio & Lucas, 2004; Linden & Rockoff, 2008; Bin & Landry, 2013; Singh, 2019).

Contrary to the conventional wisdom, we document that the environmental punishment information conveys bad news of environmental quality rather than good news to the housing market. In essence, information disclosure of environmental punishments reveals the sources of pollutants and consequently adds new information to the public. Furthermore, environmental punishments are normally viewed as salient events to the homebuyers. According to the salience theory, investors designate disproportionately higher weights to salient attributes of assets and goods (Chetty et al., 2009; Bordalo et al., 2012, 2013; Cosemans & Frehen, 2021). Environmental quality can serve as a salient feature of amenity surrounding a house, which is capitalized into housing prices in terms of hedonic price model (Chay & Greenstone, 2005; Bayer et al., 2009; Bajari et al., 2012; Currie et al., 2015; Bayer et al., 2016; Agarwal et al., 2019; He et al., 2020). Accordingly, we extrapolate homebuyers highly value the environmental punishment information, especially for houses surrounding the punished firms. In addition, the extent to which public event information disclosure affects housing prices dissipates with distance and over time (Figlio & Lucas, 2004; Linden & Rockoff, 2008; Bin & Landry, 2013; Currie et al., 2015; Singh, 2019; Mei et al., 2021). Likewise, we conjecture that the impacts of environmental punishments on housing price dissipate with distance and over time. This paper utilizes Beijing housing resale market data to explore how environmental punishment information affects housing prices. Our difference-in-differences results suggest that the housing transaction prices within 0.5 kilometers distance from the environmentally punished firms decreases approximately by 1.84% on average. The negative impacts of environmental punishments on housing transaction prices decays with distance and over time. The effects of environmental punishments on housing prices vanish around 1 kilometer distance from the environmentally punished firms to the traded housings. Hence, we take the traded houses between 1-2 kilometers distance from the punished firms as the control groups, while take the houses within 0.5 or 1 kilometer distance from the punished firms as the treatment groups. Meanwhile, the event study shows the negative impacts of environmental punishments last for 9 months and then disappear afterwards. Lastly, we examine the mechanisms of information disclosure, information dissemination and health concern of environmental punishments. The information disclosure mechanism reveals that the environmental punishments exposed to the public exert substantial negative impacts on housing prices and fortify the negative impacts on the

housing prices by environmental information search. The information dissemination mechanism articulates that the effects of environmental punishments on housing prices decay with distance and over time. The health concern mechanism illustrates that elder homebuyers and the homebuyers with children are more sensitive to the environmental punishments relative to the young single homebuyers. Moreover, the negative effects are amplified in the heating seasons and in the national political events.

The data in this research has three advantages. First, China is the largest developing country in the world and has undergone severe environmental pollution for a long history. Beijing, as the capital of China, has experienced substantial air quality changes since 2010. Hence, Beijing provides a desirable setting for this research to exploit the effects of environmental punishments on housing prices. Second, China's New Environmental Protection Law carried out since January 1, 2015, which is viewed as the most stringent environmental law in the history. China's New Environmental Protection Law requires the local law enforcement authorities record and report all punishments to the central government. The China's New Environmental Protection Law also requires local governments to increase information disclosure degree of environmental punishments to the public. It is favorable to make a clearing identification for our empirical study. Third, this research combines the firm-level environmental punishment data and the housing resale transaction data in Beijing since the implementation of China's New Environmental Law from January 2015 to December 2017. It helps to capture the heterogenous responses of homebuyers to the environmental punishments.

The remainder of the paper proceeds as follows: Section 2 introduces the evolution of environmental protection laws in China, Section 3 describes the data and our empirical strategy, Section 4 presents the empirical results and robustness checks, and Section 5 concludes.

2. The Evolution of China's Environmental Protection Law

The first Environmental Protection Law in China was promulgated on December 26, 1989. It is a fundamental law in environmental and resource protection in China. Unfortunately, the first environmental protection law doesn't specify environmental punishment measures. At the early stage of China's transition from the central-planning economy to the market-orientated economy, the central government focus on economic development rather than environmental protection. Thus, China acquires a rapid economic growth at the price of environmental pollution over the past decades. According to the Communique on China's Ecology and Environment in 2014 before the new Environmental Protection Law, there are 16 cities arriving at air quality attainment, merely accounting for 9.9% in 161 monitored cities in China.

In order to reduce pollution and protect environment, the Chinses central government set out to amend the 1989 Environmental Protection Law on April 24, 2014. The amended Environmental Protection Law titled by the New Environmental Protection Law started to implement on January 1, 2015, which is regarded as the most stringent environmental law in the history. Compared to the old Environment Protection Law, the New Environment Protection Law involves in more environmental law enforcement measures and information disclosure. The New Environment Protection Law adds new five punishment measures according to the severity of environmental law enforcement, i.e., daily fine, seal and distrain of production equipment, production reduction and suspense, administrative detention and criminal offence. Table A1 in the Appendix shows that the

five environmental punishment measures are not evenly distributed, the seal and distrain of production equipment dominates and accounts for 91.97% of total environmental punishments, the criminal offence lies at the second position by 4.41%, production reduction and suspense, and administrative detention follow by 1.18% and 1.18%, respectively, daily fine accounts for the least of 1.27%. According to the Communique on China's Ecology and Environment in 2017, there exist 233 thousand administrative penalties occurred in 2017 and the overall administrative fines arrive at 11.58 billion Chinese RMB (approximately 1.76 billion USD), which is a 2.65-times increase compared to Year 2014.

In particular, under the New Environmental Protection Law, local governments are required to record and report all the punishments conducted by the new five measurements to the central government. In addition, according to the New Environment Protection Law, the administrative departments of environmental protection at and above the county-level governments and the other related departments in local governments are responsible for supervision and implementation of environmental protection law, such as record the information on environmental law violations of firms, institutions, other producers and individuals into social credit systems, and timely disclose the information of environmental law violators to the public. In order to coordinate with the implementation of the New Environmental Protection Law, the Ministry of Ecology and Environment of the People's Republic China issued a new regulation named *Measures for Environmental Information Disclosure of Enterprises and Institutions*. It is mandatory for the firms on the list of key pollutant discharge to release the information of environmental punishments. As a result, the information of environmental punishments is almost disclosed and becoming more transparent since the implementation of the New Environmental Protection Law. In terms of the Ministry of Ecology and Environment, the information disclosure of ecological and environment punishments accounts for 85.98% in China in 2018.

3. Data and Empirical Strategy

3.1 Data

This research uses the micro data sets of firm-level environmental punishments and housing resale data in Beijing from January 2015 to December 2017. The environmental punishment data is gathered from the Evaluation Report on the New Environment Protection Law Enforcement. It contains all the firm-level environment punishments taking place from January 2015 to December 2017. As shown in Figure 1, the majority of environmental punishments took place in southern Beijing, particularly in Chaoyang District, Tongzhou District and Daxing District. In fact, since most of manufacturing firms concentrate in southern Beijing, it is easy to extrapolate that the air pollution in southern Beijing is more severe than that in the other regions in Beijing. In addition, as shown in Table A1 in the Appendix, the five environmental punishment measures are not evenly distributed, the seal and distrain of production equipment dominates and accounts for 91.97% among five environmental punishment measures from January 2015 to December 2017. Hence, it needs to point out that this research mainly analyzes and reflects the effects of the seal and distrain of production equipment punishments on the housing prices per se.

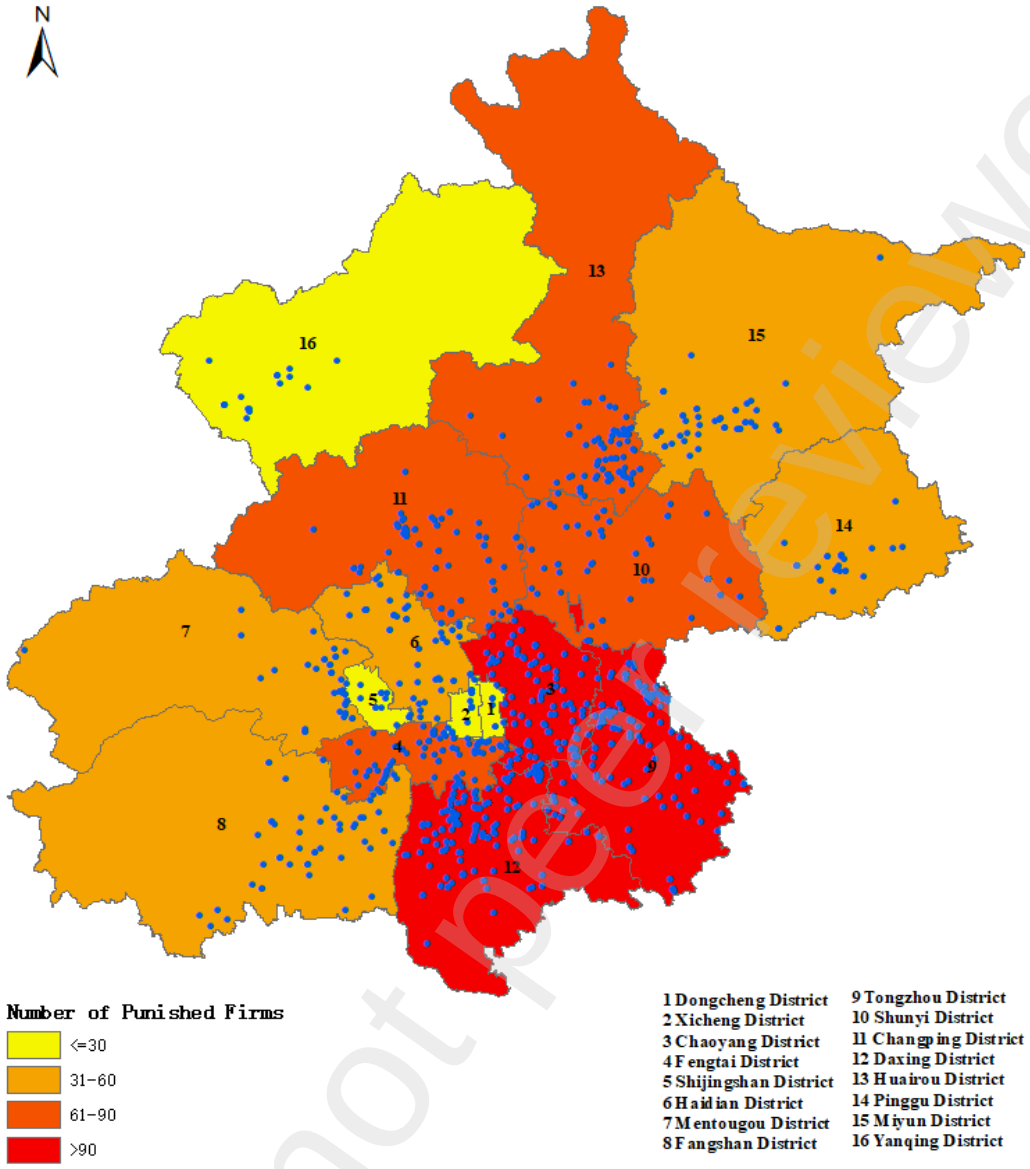

Figure 1 The Spatial Distribution of Environmentally Punished Firms in Beijing from January 2015 to December 2017

Note: The blue solid points describe the location of environmentally punished firms, while the background colors represent the number of environmentally punished firms for every district.

The enriched housing resale data are sourced from one of the largest real estate brokerages in China, which prefers to anonymity. The Beijing housing resale databases contains the information of listed housing, homebuyers, home sellers and mortgage characteristics spanning from January 2013 to December 2017. In order to merge the housing resale data with the environmental punishment data, we narrow our sample into the period of 2015-2017. Meanwhile, we rule out the housing transactions without complete information and finally obtain 169,927 observations. A concern rising from a particular brokerage firm is the reliability and representativeness of our particular data. On the one hand, as shown in Figure 2, the time trend and volatility of resale housing

transaction volume in our sample are consistent with that in Beijing over 2015-2017[1]. On the other hand, our sample accounts for 31.58% of the total second-hand housing transactions in Beijing on average from 2015 to 2017. Hence, our sample is highly representative in Beijing resale housing market. In addition, the data in this research is genuine and unbiased. The data in this research is the genuine transaction data recorded by the real estate brokerage firm rather than tax data that real estate brokerage firm provided to the tax authorities. Notwithstanding the real estate brokerage firm might fabricate the housing prices in tax data for tax avoidance motivation, it is not likely for the real estate brokerage firm to fake housing transaction prices in this confidential data for our academic study. Lastly, it needs to point out that the homebuyer and occupant of a house are the same if the homebuyer merely owns a house, while the homebuyer and occupant of a house are normally different if the homebuyer owns more houses. Generally speaking, the occupants of houses have stronger responses to the environmental punishments than the homebuyers of houses. Due to lack of information about the occupant of a house, we solely exploit the response of the homebuyers to the environmental punishments.

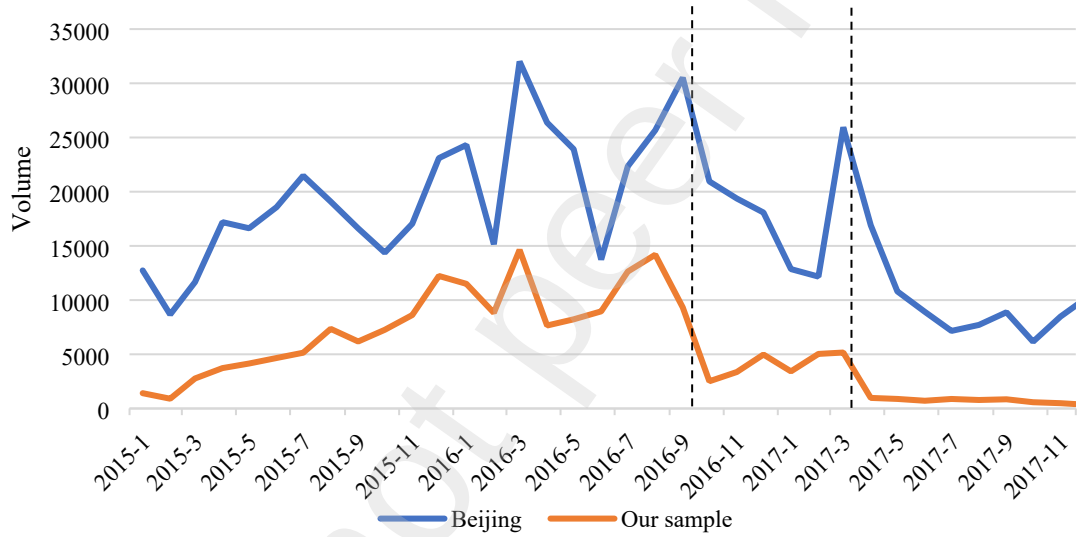

Figure 2 The Volume of Housing Resale Transactions in the Sample and in Beijing from January 2015 to December 2017

To precisely measure the distances from the environmentally punished firms to the traded houses, we obtain the registered addresses of environmentally punished firms on the Qichacha Website (https://www.qcc.com/)[2]. We are able to successfully match the registered addresses for the 1021 environmentally published firms of interest through Qichacha Website (see Appendix Table A2).

3.2 Identification

To clearly identify the effects of environmental punishments on housing prices, we apply the

[1] The total volume of housing resale transactions in Beijing are gathered at the official website of Beijing Municipal Commission of Housing and Urban-Rural Development (http://zjw.beijing.gov.cn/).

[2] Qichacha Website is a universally recognized search engine for corporate registration information in China.

difference-in-differences approach as follows:

$$\ln HP_{ijt} = \beta_0 + \beta_1 Near_{ij} \times Post_{jt} + \beta_2 Near_{ij} + \beta_3 Post_{jt} + \boldsymbol{X}'_{it}\boldsymbol{\lambda} + D_i + F_j + T_t + \varepsilon_{ijt} \quad (1)$$

In Equation (1), $\ln HP_{ijt}$ denotes the natural logarithm of transaction price for house i near punished firm j at time t. $Near_{ij}$ is a treatment dummy variable that equals to one if house i is within 0.5 kilometers distance from punished firm j and zero otherwise.[1]. The control groups in Equation (1) are houses between 1-2 kilometers distance from the punished firms. The definition of treatment and control groups is described in the next section 3.3. $Post_{jt}$ is an indicator variable that equals to one if firm j at time t is punished. The focal interaction variable $Near_{ij} \times Post_{jt}$ is the interaction term between house i and punished firm j. Thus, the coefficient of β_1 captures the average treatment effects of environmental punishments on housing prices. $X_{i,t}$ is a vector of listing housings, homebuyers and home-sellers' characteristics. The listing housing characteristics contain the numbers of rooms, halls and toilets, property fee, building age, whether near subway station or in a school district, and whether have a mortgage. The characteristics of homebuyers and home-sellers encompass gender and age of homebuyers and home-sellers. Lastly, Equation (1) controls for the district fixed effects (D_i), punished firm fixed effects (F_j), and year-month fixed effects (T_t). Standard errors are clustered at the level of district × year-month.

3.3 Defining Treatment Groups and Control Groups

To accurately estimate the effects of environmental punishments on housing prices, we need to clearly define the treatment groups and the control groups. Following Currie et al. (2015) and Mei et al. (2021), we first regress housing transaction prices on the distance from the traded houses to the nearest punished firms and then empirically define treatment groups and control groups. According to Currie et al. (2015), we construct the estimation model as follows:

$$\ln HP_{ijt} = \sum_{n=0}^{4} \chi_n d_{ij}^{\ n} \times Post_{jt} + \boldsymbol{X}'_{ijt}\boldsymbol{\varphi} + D_i + F_j + T_t + \pi_{ijt} \quad (2)$$

In Equation (2), $\ln HP_{ijt}$ denotes the natural logarithm of housing transaction price for house i close to the punished firm j at time t. $Post_{jt}$ is an indicator variable to indicate whether firm j at time t is environmentally punished. $d_{ij}^{\ n} \times Post_{jt}$ is the interaction term between the indicator $Post_{jt}$ and a quartic polynomial of the distance $d_{ij}^{\ n}$ between the traded house i and the punished firm j. $\boldsymbol{X}_{i,t}$ is a vector of housing characteristics, homebuyer characteristics and home-seller characteristics. D_i, F_j and T_t are the district fixed effects, punished firm fixed effects and year-month fixed effects, respectively. Standard errors are clustered at the district × year-month level. Thus, we can estimate the marginal effects of distances between the traded houses and the environmental punishments with an internal of 0.1 kilometers on housing prices.

[1] We utilize the longitudinal and latitudinal data of the environmentally punished firms and the traded houses from Baidu Map (http://lbsyun.baidu.com/) to compute their geographical distances.

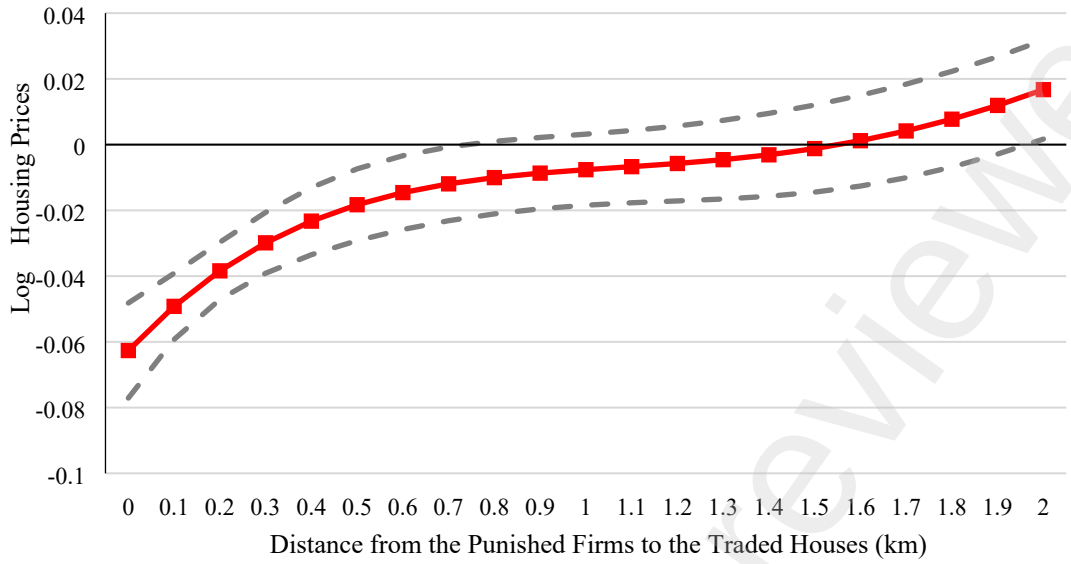

Figure 3 The Marginal Effects of Environmental Punishments on Housing Prices with Distance

Note: The horizontal axe is the geographical distance between the traded houses and environmentally punished firms. The vertical axe is the natural logarithm of housing price. The red line in the graph indicates the estimated coefficients while the dotted line represents the 95% confidence interval.

As shown in Figure 3, the transaction prices of houses within 0.5 kilometers distance from the environmentally punished firms decline considerably after the environmental punishments occur, while the transaction prices of houses between 0.5-1 kilometers distance from the environmentally punished firms slightly decrease after the environmental punishments occur. By contrast, the transaction prices of houses between 1-2 kilometers distance from the punished firms do not significantly abate since the environmental punishments occur. Hence, as shown in Figure 4, we define the traded houses between 1-2 kilometers distance from the punished firms as the control groups, while take the houses within 0.5 kilometers distance from the punished firms as the treatment groups. In the robustness checks, we take the traded houses within 1 kilometer distance from the environmental punished firms as the treatment groups. Table A4 in the Appendix illustrates that the baseline results are robust.

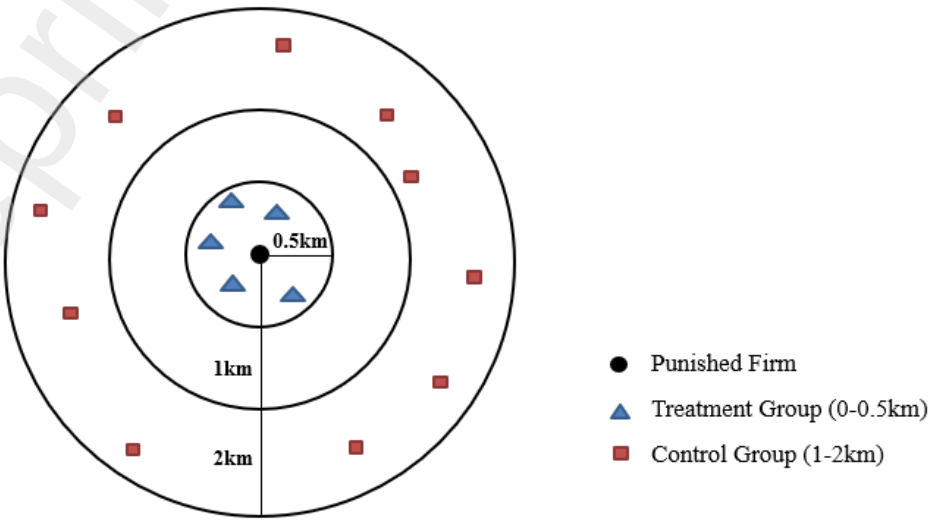

Figure 4 The Schematic Diagram of the Treatment Groups and Control Groups

3.4 Parallel Trend Tests

In order to identify ex-ante and ex-post effects of environmental punishments on housing prices, we institute an event study as follows:

$$\ln HP_{ijt} = \sum_{t\neq -1} \alpha_t Near_{ij} \times dt_{jt} + \omega_1 Near_{ij} + \sum_t \delta_t dt_{jt} + \boldsymbol{X}'_{it}\boldsymbol{\theta} + D_i + F_j + T_t + \xi_{ijt} \quad (3)$$

In Equation (3), dt_{jt} is a monthly dummy variable that equals to one if it is t months before or after the environmental punishment happens. We take one month before an environmental punishment happened as the reference month. The coefficients of $\alpha_t (t \neq -1)$ are the magnitudes of housing transaction prices differences between treatment groups and control groups in each month before or after the environmental punishments occur. The controlling variables are the same as those in Equation (2).

3.5 Descriptive Analysis

As shown in Column (1), the average housing transaction price is around 47043 Chinese RMB (approximately 7362 US dollars) per square meter in our sample. To describe the difference-in-differences of housing prices between the treatment groups and the control groups before and after the environmental punishments occur, we divide our sample into four cohorts. Comparing Columns (4)-(5) with Columns (2)-(3), we find that the average transaction price of houses in the control groups are greater than that in the treatment groups. Apparently, the transaction prices of houses near the environmentally sensitive facilities are lower than those further away from the environmentally sensitive facilities. To further demonstrate the difference-in-differences between the treatment groups and the control groups before and after the environmental punishments occur, T-tests in Column (6) show that compared with the control groups, the housing transaction prices in the treatment groups dramatically decrease 1175.57 Chinese RMB per square meter since the environmental punishments occur. The definition and metrics of key variables in this paper are described in Table A3 in the Appendix.

Table 1 Summary Statistics of Major Variables

	Full Sample	Treatment Groups: 0-0.5 Kilometers		Control Groups: 1-2 Kilometers		Difference-in-Differences
Variables	(1)	(2) Before punishment	(3) After punishment	(4) Before punishment	(5) After punishment	(6) [(3)-(2)]-[(5)-(4)]
HP (CNY p.s.m.)	47043.36 (21097.59)	42480.58 (18994.97)	45907.22 (20139.97)	49406.70 (21609.54)	54008.92 (22246.74)	-1175.57***
Housing Characteristics						

Room	2.05	2.04	2.02	2.07	2.05	-0.0017
	(0.78)	(0.74)	(0.77)	(0.79)	(0.80)	
Hall	1.17	1.18	1.18	1.16	1.18	-0.0304***
	(0.52)	(0.52)	(0.53)	(0.52)	(0.54)	
Toilet	1.20	1.18	1.20	1.20	1.23	-0.0166**
	(0.45)	(0.43)	(0.44)	(0.46)	(0.47)	
Fee	1.47	1.41	1.48	1.47	1.58	-0.0381**
(CNY	(1.06)	(0.98)	(1.09)	(1.08)	(1.11)	
p.s.m.)						
Age	16.15	15.44	15.62	16.94	16.70	0.4215***
(yrs)	(8.42)	(7.97)	(7.90)	(8.86)	(8.78)	
Mort	0.08	0.06	0.12	0.06	0.12	-0.0065*
	(0.27)	(0.24)	(0.32)	(0.23)	(0.32)	
Subw	0.72	0.67	0.74	0.72	0.82	-0.0304***
	(0.45)	(0.47)	(0.44)	(0.45)	(0.39)	
Schl	0.78	0.79	0.74	0.82	0.78	-0.0099*
	(0.41)	(0.41)	(0.44)	(0.39)	(0.42)	
Homebuyer and Home-seller Characteristics						
BAge	35.84	35.91	36.13	35.96	36.28	-0.0965
	(9.60)	(9.76)	(10.16)	(9.35)	(10.08)	
SAge	47.19	46.58	46.35	48.29	47.62	0.4456**
	(14.15)	(13.83)	(13.60)	(14.48)	(14.42)	
BMale	0.52	0.53	0.52	0.51	0.51	-0.0062
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	
SMale	0.55	0.56	0.55	0.55	0.53	-0.0027
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	
Obs.	169,927	24,435	12,188	40,134	17,560	

Note: ***p<0.01, **p<0.05, *p<0.1. *HP* denotes housing transaction price per square meter in Chinese Yuan. *Room*, *Hall* and *Toilet* stand for the numbers of rooms, halls and toilets of the traded houses, respectively. *Fee* denotes property management fee per square meter. *Age* denotes housing age. *Mort* is an indicator equal to one if the housing transaction involves in mortgage. *Subw* and *Schl* are indicators equal to one if the traded house is close to subway station or school district, respectively. *BAge* and *SAge* denote homebuyer's age and home-seller's age, respectively. *BMale* and *SMale* are gender indicator variables if the homebuyer and home-seller are male. Column (1) describes the full sample. Column (2) and Column (3) describe the summary statistics of housing transactions within 0.5-kilometer distance from an environmentally punished firm before and after the punishment, respectively. Column (4) and Column (5) illustrate the summary statistics of housing transactions of 1-2kilometer distance from a punished firm before and after the punishments, respectively. Column (6) presents difference-in-differences results between treatment group and control group before and after the punishments. The standard deviations are shown in the parentheses. All the continuous variables are winsorized at 1% level.

4. Results

4.1 Baseline Results

As expected, Table 2 reveals that the environmental punishments have negative effects on the housing transaction prices within 0.5 kilometers distance from the environmentally punished firms. As shown in Column (4) in Table 2, compared with the transaction prices of houses between 1-2 kilometers distance from the environmentally punished firms, the transaction prices of houses within 0.5 kilometers distance from the environmentally punished firms abate approximately 1.84% since the environmental punishments occur if we control for the district fixed effects, year-month fixed effects and punished firm fixed effects. It suggests that the housing prices decrease 865.60 Chinese RMB (=47043.36× 0.0184) per square meter on average since the environmental punishments occur. In contrast to the conventional wisdom, the results ascertain that the environmental punishments normally reflect the severity of air pollution rather than the amelioration of environmental quality in the short run. In other words, the environmental punishments deliver bad news of environmental quality to the homebuyers. On the one hand, owing to the asymmetric information, the homebuyers could not know the exact origins of pollutant emissions, the environmental punishments add new information of environmental pollution to the homebuyers in the sense that they normally occur in the polluted areas. On the other hand, environmental quality could not fundamentally ameliorate in the short run. In addition, Column (4) in Table 2 indicates that the transaction prices of houses within 0.5 kilometers distance from the environmentally punished firms is 2.89% less than that of the transaction prices of houses between 1-2 kilometers distance from the environmentally punished firms. For robustness checks, the baseline results are robust if we control for district× year-month fixed effects or firm× year-month fixed effects. Similarly, Table A4 in the Appendix displays that the baseline results are also robust if the treatment groups are the houses within 1 kilometer distance from the punished firms.

Table 2 The Baseline Results of Environmental Punishments and Housing Prices Within 0.5 Kilometers Distance From the Environmentally Published Firms

ln *HP*	(1)	(2)	(3)	(4)	(5)
*Near * Post*	-0.0256***	-0.0259***	-0.0293***	-0.0184***	-0.0231***
	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0074)
Near	-0.0160***	-0.0154***	-0.0132***	-0.0289***	-0.0281***
	(0.0038)	(0.0038)	(0.0038)	(0.0033)	(0.0035)
Post	0.0004	0.0005	0.0033	0.0002	
	(0.0055)	(0.0033)	(0.0055)	(0.0043)	
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes

Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.76	0.76	0.76	0.84	0.85

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. $Near$ is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. $Post$ is an indicator variable that equals to one if the housing transaction takes place after the environmental punishment. The focal independent variable $Near \times Post$ is the interaction of the houses within 0.5 kilometers distance from the punished firms and the month dummy variables after environmental punishments occur. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.

To conduct a parallel trend test, we utilize an event study to examine the housing price changes before and after the environmental punishments occur in terms of Equation (3). As shown in Figure 5, the differentials of housing transaction prices between the treatment groups and the control groups are not significant before the environmental punishments occur. By contrast, the environmental punishments have an inverse U-shape effects on the housing transaction prices since the environmental punishments occur. The decreases in housing transaction prices are smaller and less significantly in the first four months, because the dissemination of environmental punishment information takes time. It is noteworthy that the negative effects of environmental punishments on the housing prices are merely persistent for 9 months and then disappear. The transaction prices of houses within 0.5 kilometers distance from the environmental punished firms decrease from 1.96% in the first month to the crest of 4.00% in the seventh month and then decrease to 1.39% in the tenth month after the environmental punishments happen. Apparently, it turns out that the parallel trend assumption is valid. It further documents that the dissemination of environmental punishment information decays over time. As shown in Figure A1 in the Appendix, the cumulative effects of environmental punishments on housing prices are substantially increasing since the environmental punishments occur. Combined with Figure 3, it is reasonable to infer that the impacts of the environmental punishments on the housing prices decay across distance and over time.

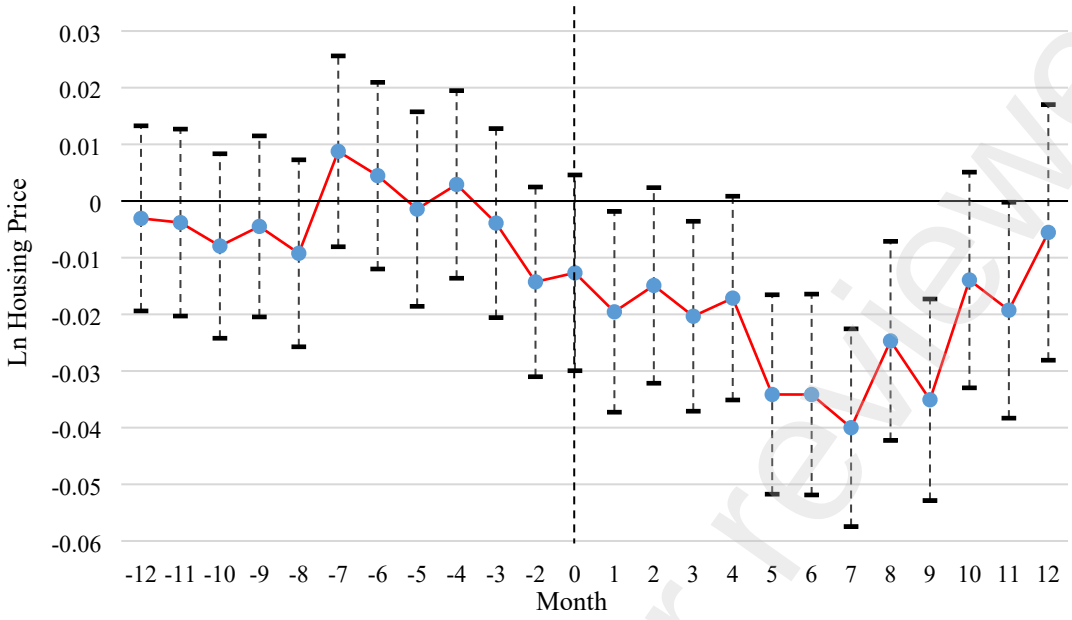

Figure 5. The Parallel Trend Tests

Note: The horizontal axe represents the months before and after the environmental punishments occur. The vertical axe denotes the coefficients of the interaction of treatment group variable, *Near*, and the month dummy variables, *dt*, before and after the environmental punishments occur. The solid blue points represent the estimation of coefficients, while the dashed black lines delineate 95% confidence intervals.

4.2 Mechanisms

4.2.1 Information Disclosure Mechanism

The baseline results indicates that the environmental punishments convey a negative signal of environmental quality to homebuyers. Hence, environmental punishments involve in information disclosure of environmental quality. Thus, to prove the information disclosure mechanism of environmental punishments in housing prices, we construct an information disclosure dummy variable of environmental punishment, *Exposed*, which equals to one if the environmental punishment is exposed to the public. To further elucidate the information disclosure mechanism, we develop a triple interaction term between treatment groups, environmental punishment and its information disclosure. As shown in Table 3, the triple interactions between treatment groups, environmental punishment and its information disclosure are significantly negative, suggesting that compared with the environmental punishments undisclosed to the public, the disclosed environmental punishments could enhance the negative effects of environmental punishments on housing prices. It is in line with the information disclosure mechanism.

Table 3 The Information Disclosure Effects of Environmental Punishments on Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Exposed*	-0.0665***	-0.0673***	-0.0939***	-0.0330**	-0.0803***

	(0.020)	(0.020)	(0.019)	(0.014)	(0.017)
*Near * Post*	-0.0157***	-0.0156***	-0.0155***	-0.0119*	-0.0105
	(0.006)	(0.006)	(0.006)	(0.007)	(0.009)
*Near * Exposed*	-0.0028	-0.0017	0.0024	0.0079	0.0103
	(0.005)	(0.005)	(0.005)	(0.007)	(0.008)
*Post * Exposed*	-0.0158	-0.0150	-0.0120	0.0170**	
	(0.012)	(0.012)	(0.012)	(0.008)	
Near	-0.0161***	-0.0160***	-0.0153***	-0.0318***	-0.0317***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Post	0.0096*	0.0094	0.0117**	-0.0036	
	(0.006)	(0.006)	(0.006)	(0.005)	
Exposed	0.0412***	0.0403***	0.0406***		
	(0.004)	(0.004)	(0.004)		
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.761	0.762	0.767	0.844	0.858

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment. *Exposed* is a dummy variable that equals to one if the environmental punishment is exposed to the public. The focal independent variable *Near * Post * Exposed* is triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the exposed environmental punishments. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.

4.2.2 Information Dissemination Mechanism

The second mechanism related to environmental punishments is the information dissemination of environmental punishments on housing prices. As individual information searching behavior could capture the speed and scope of information propagation (Da et al., 2011; Wu & Deng, 2015; Baker & Fradkin, 2017; Xu et al., 2021), we apply the Baidu Search Index of environmental pollution to represent the public online information searching and the information dissemination of environmental punishments. Thus, we create a dummy variable of *Search* as the proxy for the

total monthly online search volume of environmental pollution in Beijing[]. As shown in Table 4, the triple interaction of *Near* Post* Search* is significantly negative to housing transaction prices. Controlling for the characteristics of listed housing, homebuyers and home-sellers, district fixed effects, punished firm fixed effects and year-month fixed effects, Column (4) in Table 4 reveals that a standard deviation of Baidu search index on environmental pollution decreases the housing transaction prices of houses within 0.5 kilometers distance from the environmentally published firms by 2.23% since the environmental punishments occur. It suggests that information dissemination of environmental punishments serves as a conduit for housing prices.

Table 4 The Information Dissemination Effects of Environmental Punishments on Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Search*	-0.0437***	-0.0436***	-0.0456***	-0.0223***	-0.0246***
	(0.007)	(0.007)	(0.007)	(0.006)	(0.008)
Near Post*	-0.0270***	-0.0272***	-0.0309***	-0.0183***	-0.0227***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)
Near Search*	0.0220***	0.0222***	0.0229***	-0.0145***	-0.0127**
	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
Post Search*	0.0355***	0.0353***	0.0370***	0.0043	
	(0.005)	(0.005)	(0.006)	(0.003)	
Near	-0.0165***	-0.0159***	-0.0136***	-0.0289***	-0.0283***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
Post	0.0007	0.0007	0.0035	0.0001	
	(0.005)	(0.005)	(0.005)	(0.004)	
Search	-0.0296***	-0.0296***	-0.0301***		
	(0.005)	(0.005)	(0.005)		
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.762	0.763	0.768	0.844	0.859

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable ln *HP* is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place

[] The online information searching data is from the Baidu Search Index (http://index.baidu.com/). We normalize the online searching index to one.

after the environmental punishment. $Search$ is the normalized proxy of public online information searching behavior. The focal independent variable $Near * Post * Search$ is triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the Baidu Search Index of environmental pollution in Beijing. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

4.2.3 Health Concern Mechanism

As mentioned above, environmental pollution could give rise to health concerns. Fundamentally, older people have more health problems than the young people, and consequently care more about health than the young people. Thus, we hypothesize that older homebuyers have stronger responses to environmental punishments than young homebuyers. The homebuyers in our sample are quite young with a median age of 33(see Fig. A1 in the Appendix). Thereby, in order to testify the health mechanism of environmental punishments on housing prices, we divide the homebuyers into three cohorts as follows: younger homebuyers aged 30 and below, middle-aged homebuyers aged 31-40 and older homebuyers aged 41 and above.

As shown in Table 5, the environmental punishments have greater effects on housing prices of old-aged and middle-aged homebuyers than that of younger homebuyers, the triple interaction coefficients of environmental punishments with old-aged and middle-aged homebuyers are significantly negative. Hence, the old-aged and middle-aged homebuyers have significantly lower willingness to pay for the housing prices than the young homebuyers since the environmental punishments occur. For instance, controlling for the district fixed effects, year-month-fixed effects and punished firm fixed effects, Column (4) suggests that the environmental punishments depress the housing transaction prices by 1.80% and 0.85% for the homebuyers aged 31-40 and the homebuyers aged 41 and above, respectively. It implies the transaction prices of the homebuyers aged 41 and above and the homebuyers aged 31-40 are 399.87 Chinese RMB (=47043.36×0.0085) per square meter and 846.78 Chinese RMB (=47043.36×0.0180) per square meter less than that of the homebuyers aged 30 and below, respectively. Apparently, the old-aged homebuyers and middle-aged homebuyers care more about health than the younger homebuyers.

For robustness checks, we adopt the WHO (World Health Organization) criteria to categorize age cohorts as follows: young people aged 44 and below, middle-aged people aged 45 to 59 and old people aged 60 and above. As shown in Fig. A1, the homebuyers aged 60 and above only account for 5% in our sample, thus we depress the old-aged homeowners and divide the homebuyers into two cohorts of young homebuyers aged 44 and below and middle-aged homebuyers aged 45 and above. As shown in Table A5, the triple interaction of environmental punishments with middle-aged homebuyers also has greater impacts on the housing prices than that of environmental punishments with young-aged homebuyers.

Table 5 The Results of Environmental Punishments and Housing Prices across Homebuyers' Ages

ln *HP*	(1)	(2)	(3)	(4)	(5)
*Near * Post * Old*	-0.0104*	-0.0108*	-0.0118**	-0.0085*	-0.0084*
	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
*Near * Post * Mid*	-0.0187***	-0.0193***	-0.0197***	-0.0180***	-0.0170***
	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
*Near * Post*	-0.0145***	-0.0143***	-0.0173***	-0.0075*	-0.0125***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)
Near	-0.0191***	-0.0189***	-0.0172***	-0.0329***	-0.0325***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Post	-0.0047*	-0.0047*	-0.0022	-0.0048	
	(0.003)	(0.003)	(0.003)	(0.003)	
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District × Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm × Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.761	0.761	0.766	0.844	0.858

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable ln *HP* is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment. *Old* is a dummy variable that equals to one if the homebuyer's age is 41 and above. *Mid* is a dummy variable that equals to one if the homebuyer's age is 31-40. The focal independent variable *Near * Post * Old* is the triple interaction of traded houses within 0.5 kilometers distance from environmentally published firms, the month dummy variables after environmental punishments occur and the homebuyers aged 41 and above. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

In order to provide more evidence on health concern mechanism of environmental punishments, Table 6 presents the results of environmental punishments on prices of the traded housing surrounding school districts. In theory, households with young children are more sensitive to the environmental punishments as they care more about their children's health. Notwithstanding we do not have the information of whether homebuyers have children, we have the exact locations whether the housing transactions are in the school districts. As such, we hypothesize that the homebuyers who buy dwellings in the school districts are those with children and care more about health than homebuyers without children. As shown in Table 6, the interaction coefficients of the environmental

punishments in the school districts are significantly negative, suggesting that homebuyers with children pay lower housing prices for the air pollution. Column (3) in Table 6 indicates that the environmental punishments curtail down the housing transaction prices by 3.91% in the school districts by controlling for the district×year-month fixed effects. It suggests the transaction prices of the homebuyers with children are 1839.40 Chinese RMB (=47043.36×0.0391) per square meter less than that of the homebuyers without child in terms of the mean of housing transaction prices. Hence, it further documents that health concerns are essential to interpret the effects of environmental punishments on the housing prices. In addition, as wind direction affects air pollution flows, we explore how wind direction affects the effects of environmental punishments on housing prices. Unfortunately, as shown in Table A6, the triple interaction coefficients of *Near* Post* Downwind* are not significant. It suggests that the homebuyers do not care whether the houses locate at the downwind directions from the environmentally punished firms, they merely care about the geographical distance from the environmentally punished firms.

Table 6 The Results of Environmental Punishments and Housing Prices in School Districts

ln *HP*	(1)	(2)	(3)
Near Post* School*	-0.0378***	-0.0392***	-0.0391***
	(0.012)	(0.012)	(0.012)
Near Post*	-0.0179***	-0.0178***	-0.0211***
	(0.006)	(0.006)	(0.006)
Near School*	0.0158**	0.0159**	0.0165**
	(0.008)	(0.008)	(0.008)
Post School*	0.0419***	0.0425***	0.0398***
	(0.008)	(0.008)	(0.008)
Near	-0.0189***	-0.0183***	-0.0163***
	(0.004)	(0.004)	(0.004)
Post	-0.0082	-0.0083	-0.0049
	(0.006)	(0.006)	(0.006)
Housing Characteristics	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes
Home-seller Characteristics	No	Yes	Yes
District FE	Yes	Yes	No
Year-Month FE	Yes	Yes	No
District×Year-Month FE	No	No	Yes
Obs.	94,317	94,317	94,317
Adj. R-squared	0.760	0.761	0.766

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable ln *HP* is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment. *School* is an indictor variable that equals to one if the housing transactions occur in a school district. We control for the characteristics of listed housing, homebuyers and home-sellers. The focal independent variable *Near* Post* School* is the triple interaction of traded houses within 0.5 kilometers

distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the housing transactions in a school district. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

4.3 Robustness Checks

4.3.1 Whether the Welfare of Affected Employees in the Punished Firms Influences Housing Prices

A potential alternative explanation is that the negative effects of environmental punishments on housing prices might be caused by the affected employees in the punished firms. A plausible argument is that the employees would confront unemployment or salary abatement if their employers are environmentally punished, therefore reduce housing demand and housing prices. Owing to the lack of detailed data on the affected employees in the punished firms, we classify the five measures of environmental punishments into two cohorts: light punishments including daily fine, seal and distrain of production equipment and severe punishments including production reduction and suspense, administrative detention and criminal offence. Generally speaking, the severe punishments are highly relevant to firms' production and closure, which decides the employees' salary and unemployment. For this reason, we construct a severe punishment proxy to represent the affected employees. As shown in Table 7, the triple interaction coefficients of the traded houses within 0.5 kilometers distance from the environmentally published firms, the months since environmental punishments occur and the severe environmental punishments are significantly positive, which is converse to our expectation. It suggests that the results in this research are not driven by the affected employees.

Table 7 The Effects of the Affected Employees in the Environmentally Punished Firms on Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Closure*	0.2789***	0.2688***	0.2793***	0.1573***	0.1706**
	(0.081)	(0.081)	(0.081)	(0.053)	(0.074)
Near Post*	-0.0280***	-0.0282***	-0.0320***	-0.0179***	-0.0222***
	(0.006)	(0.005)	(0.006)	(0.006)	(0.008)
Near Closure*	0.0016	0.0011	-0.0033	0.0175	0.0159
	(0.018)	(0.017)	(0.017)	(0.022)	(0.023)
Post Closure*	-0.1317**	-0.1234*	-0.1342**	-0.0650	
	(0.064)	(0.063)	(0.065)	(0.042)	
Near	-0.0161***	-0.0155***	-0.0130***	-0.0300***	-0.0293***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Post	0.0011	0.0013	0.0042	-0.0001	
	(0.006)	(0.006)	(0.006)	(0.004)	
Closure	0.0151	0.0159	0.0178*		
	(0.010)	(0.010)	(0.010)		
Housing Characteristics	Yes	Yes	Yes	Yes	Yes

Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.762	0.763	0.768	0.844	0.859

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. $Near$ is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. $Post$ is a dummy variable that equals to one if the housing transaction takes place after the environmental punishments occur. $Closure$ is an indicator that equals to one if the environmental punishments are production reduction and suspense, administrative detection or criminal offence. The focal independent variable $Near * Post * Closure$ is the triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the severe environmental punishments. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.

4.3.2 Whether Environmental Punishments Affect Environmental Quality in the Short Run

Our results verify that the environmental punishments convey bad news of environmental quality to the housing market in the short time. To corroborate whether environmental punishments could improve environmental quality in the short run, we need to explore the subsequent environmental performance of penalized firms. As most of environmentally punished firms in our data are unlisted firms, the firm-level pollution emission data are not available. As such, we could not directly measure the subsequent environmental performance of penalized firms. However, we could use the monitoring-station data on air pollutant to indirectly measure the subsequent environmental quality. We collect the monitoring-station-level air pollution data from Beijing Municipal Ecological and Environmental Monitoring Center from January 2015 to December 2017[] and merge with the environmental punishment data. Following Heyes and Zhu (2019), we employ the following specification to estimate the air pollution concentrations surrounding the traded houses:

$$Pollution_{it} = \sum_{k} w_{ik} Monitor_{kt} \quad (4)$$

In Equation (4), $Pollution_{it}$ denotes the estimated air pollutant concentrations surrounding

[] The data are available at the website www.bjmemc.com.cn.

house i at year-month t, $Monitor_{kt}$ stands for the surrounding monitoring station k at year-month t, w_{ik} denotes the weight between firm i and the surrounding monitoring station k. As shown in Figure 6, following Heyes and Zhu (2019), we utilize the following equations to compute the weights by wind speed and direction, and the distances between monitoring stations and houses:

$$w_{ik} = \frac{\varphi_k}{\sum \varphi_{ik}}, \varphi_{ik} = \frac{windspeed * \cos|\theta_{ik} - \theta_{wind}|_{>0}}{d_{ik}} \quad (5)$$

In Equation (5), $windspeed$ denotes the wind speed in Beijing. d_{ik} represents the geographical distance between monitoring station k and house i. $\cos|\theta_{ik} - \theta_{wind}|$ is the cosine coefficient between the wind direction, azimuth of house i and monitoring station k. We rule out all the negative cosine coefficients because air pollutants could not spread upwind.

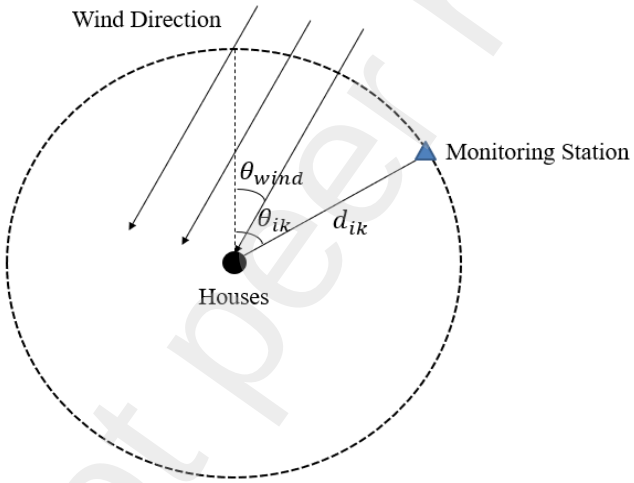

Figure 6 The Schematic Diagram of the Estimation on Air Pollution

As shown in Table 8, all the surrounding air pollutant concentrations including $PM_{2.5}$, $PM_{10}, SO_2, NO_2, O_3, CO$ are not significantly affected by the environmental punishments of firms. It suggests that environmental punishments could not change air quality dramatically in the short time per se. Indeed, the environmental punishments might stem from the weak institutions in the extremely polluted areas and could not change environmental quality in the short run (Auffhammer & Maximilian, 2011; Duflo et al., 2013).

Table 8 The Results of Environmental Punishments and Air Pollutant Concentrations

	(1)	(2)	(3)	(4)	(5)	(6)
	PM2.5	PM10	SO2	NO2	O3	CO
*Near * Post*	0.0878	-0.0914	-0.0053	0.1643	0.0395	0.0002
	(0.213)	(0.325)	(0.049)	(0.155)	(0.070)	(0.004)
Near	-0.0140	0.0673	0.0073	-0.0713	-0.0077	-0.0007

	(0.083)	(0.144)	(0.023)	(0.062)	(0.034)	(0.001)
Post	0.1351	0.3756	0.0287	0.1587	0.1883	-0.0062
	(0.265)	(0.418)	(0.072)	(0.217)	(0.115)	(0.005)
Housing Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Home-seller Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	94,202	94,202	94,202	94,202	94,202	94,202
Adj. R-squared	0.982	0.966	0.973	0.925	0.934	0.985

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variables are air pollutant concentrations including $PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, CO, surrounding the traded houses i at year-month t. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishments occur. The focal independent variable $Near*Post$ is the interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms and the month dummy variables after environmental punishments occur. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level. As 115 traded houses locate at the upwind of monitoring stations, the total observation is 94,202 (=94,317-115).

4.4 The Overlapping Effects of Environmental Punishments

In the above analysis, we merely consider the mixed and overall effects of environmental punishments on the housing transaction prices within 0.5 kilometers distance from the environmentally punished firms, but not take the overlapping effects of environmental punishments into account. As shown in Table 9, 7.51% (=6.12%+1.24%+0.12%+ 0.03%) of the traded houses are surrounded by two and more environmentally punished firms within 0.5 kilometers distance from the traded houses. Hence, we isolate the overlapping effects of multiple environmental punishments on the housing prices from the overall effects of environmental punishments on the housing prices within 0.5 kilometers distance from the traded houses.

Table 9 The Number of Punished Firms within 0.5 Kilometers Distance from the Traded Houses in Our Sample

The number of punished firms	0	1	2	3	4	5	Total
Obs.	57,694	29,542	5,775	1,168	110	28	94,317

Percentage (%)	61.17	31.32	6.12	1.24	0.12	0.03	100

As shown in Columns (4) in Table 10, the two and more environmental punishments lead to the transaction prices of the traded houses within 0.5 kilometers distance from the punished firms decline by 4.56% relative to one environmental punishment, while the single environmental punishment gives rise to the transaction prices of the traded houses within 0.5 kilometers distance from the punished firms decline by 1.17% relative to no environmental punishments. For robustness checks, we develop an interaction term of environmental punishments with the number of punished firms within 0.5 kilometers distance from the traded houses. As shown Column (4) in Table A7 in our paper, the interaction of environmental punishments with the number of environmentally punished firms within 0.5 kilometers distance from the traded houses significantly curtailed down the housing transaction prices by 3.15%. It also suggests that the overlapping effects of environmental punishments on housing price are pronounced.

Table 10 The Overlapping Effects of Environmental Punishments on the Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Overlap*	-0.0132*	-0.0130*	-0.0197**	-0.0456***	-0.0794***
	(0.008)	(0.008)	(0.008)	(0.012)	(0.015)
Near Post*	-0.0233***	-0.0236***	-0.0259***	-0.0117**	-0.0150**
	(0.006)	(0.006)	(0.006)	(0.005)	(0.007)
Near	-0.0160***	-0.0154***	-0.0132***	-0.0295***	-0.0281***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
Post	0.0005	0.0006	0.0034	0.0009	
	(0.006)	(0.005)	(0.005)	(0.004)	
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.760	0.761	0.766	0.844	0.858

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable ln *HP* is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment occurs. *Overlap* is an indictor variable that equals to one if there are two and more environmentally punished firms within 0.5 kilometers distance from the traded houses. The focal independent variable *Near* Post* Overlap* is the triple interaction of the traded houses within 0.5 kilometers distance from

the environmentally published firms, the month dummy variables after environmental punishments occur and the indicator of the two and more environmentally punished firms within 0.5 kilometers distance from the traded houses. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

4.5 External Shocks

4.5.1 The Heating Seasons

It is well known that the winter heating policies started in 1958 and are widespread in North China since the New Millennium. Boilers are widely used for winter heating in China, and coal is the primary fuel of boilers in the heating season. As coal combustion can produce air pollutants, air quality is worsening in the heating seasons. We hypothesize that homebuyers have strong responses to the environmental punishments in the heating season. In North China, the heating season normally starts from the November 15th every year to the March 15th in the next year. Thus, we generate a dummy variable of heating season and testify whether environmental punishments have greater effects on housing prices in the heating seasons. As shown in Table A1, there exist 361 of environmental punishments in the heating season, which account for 35.36% in our sample. As shown in Column (3) in Table 11, relative to non-heating seasons, the environmental punishments give rise to the housing transaction prices decline by 4.74% in the heating seasons controlling for housing, homebuyers and home sellers characteristics and the district × year-month fixed effects. Accordingly, the heating seasons significantly exacerbate air quality and augment the impacts of environmental punishments on the housing prices.

Table 11 The Results of Environmental Punishments and Housing Prices in the Heating Seasons

ln *HP*	(1)	(2)	(3)
*Near * Post * Heat*	-0.0436***	-0.0437***	-0.0474***
	(0.013)	(0.013)	(0.013)
*Near * Post*	-0.0104	-0.0106	-0.0128*
	(0.008)	(0.008)	(0.008)
*Near * Heat*	0.0289**	0.0291**	0.0289**
	(0.012)	(0.012)	(0.013)
*Post * Heat*	0.0333***	0.0334***	0.0378***
	(0.009)	(0.009)	(0.009)
Near	-0.0258***	-0.0253***	-0.0230***
	(0.005)	(0.005)	(0.005)
Post	-0.0114	-0.0114	-0.0103
	(0.007)	(0.007)	(0.007)
Heat	-0.0407***	-0.0407***	-0.0408***
	(0.010)	(0.010)	(0.010)
Housing Characteristics	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes

Home-seller Characteristics	No	Yes	Yes
District FE	Yes	Yes	No
Year-Month FE	Yes	Yes	No
District×Year-Month FE	No	No	Yes
Obs.	94,317	94,317	94,317
Adj. R-squared	0.761	0.762	0.767

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is an indicator variable that equals to one if the housing transaction takes place after the environmental punishment occurs. *Heat* is a dummy variable that equals to one if housing transactions occur in the heating seasons. The focal independent variable *Near* Post* Heat* is the triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the heating seasons. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

4.5.2 The Important National Events

Typically, the important national events could give rise to more public attention and media coverage of air quality. For instance, there are more media reports of pollutant emissions in the important national events such as the Spring Festival, National People's Congress (NPC), Chinese People's Political Consultative Conference (CPPCC), and the National Day. Hence, the homebuyers care more about air quality in the important national events. We hypothesize that the environmental punishments have greater impacts on the housing prices in the important national events. As shown in Column (3) in Table 12, relative to ordinary days, the environmental punishments result in the housing transaction price decline by 4.73% in the important national events. Hence, it extrapolates that the important national events attract homebuyers' attention and amplify the impacts of environmental punishments on the housing prices.

Table 12 The Results of Environmental Punishments and Housing Prices in the Important National Events

$\ln HP$	(1)	(2)	(3)
Near Post* Event*	-0.0529***	-0.0533***	-0.0473***
	(0.013)	(0.013)	(0.013)
Near Post*	-0.0143**	-0.0145**	-0.0186***
	(0.007)	(0.007)	(0.007)
Near Event*	-0.0016	-0.0014	-0.0026
	(0.007)	(0.007)	(0.007)
Post Event*	-0.0059	-0.0060	-0.0146
	(0.010)	(0.010)	(0.010)
Near	-0.0155***	-0.0150***	-0.0128***
	(0.004)	(0.004)	(0.004)

Post	0.0017	0.0018	0.0058
	(0.006)	(0.006)	(0.006)
Event	0.0025	0.0024	0.0055
	(0.009)	(0.009)	(0.008)
Housing Characteristics	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes
Home-seller Characteristics	No	Yes	Yes
District FE	Yes	Yes	No
Year-Month FE	Yes	Yes	No
District×Year-Month FE	No	No	Yes
Firm FE	No	No	No
Firm×Year-Month FE	No	No	No
Obs.	94,317	94,317	94,317
Adj. R-squared	0.761	0.762	0.767

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is an indicator variable that equals to one if the housing transaction takes place after the environmental punishment occur. *Event* is a dummy variable that equals to one if housing transactions occur in the important national events. The focal independent variable *Near* Post* Event* is the triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the important national events. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.

5. Robustness Checks

In addition to the housing ownership market, we turn to the housing rental market and explore the effects of environmental punishments on rental prices for the robustness checks. Similar to the homeownership market, we also hypothesize that home renters tend to pay lower prices for the houses near the environmentally punished firms. To verify our hypothesis, we collect the community-level listing rental price data in Beijing spanning from January 2015 to December 2017 from the Xitai Database[]. As shown in Table 13, the environmental punishments have no significant effects on the rental prices. It is not aligned to our expectation. By contrast to housing prices, the results of rental price might rise from high adjustment cost of rent contracts, the rental price inertia of landlords and the rigid demand of tenants in Beijing (Genesove, 2003; Englund et al., 2008; Suzuki et al., 2021; Tsai, 2021).

[] Xitai Database is a popular and major real estate listing price information platform in China (See https://www.creprice.cn/). Due to the lack of individual rental transaction price data, this research uses the community-level listing rental prices to testify the effects of environmental punishments on the rental prices. In theory, the listing rental prices are better to capture the renters' marginal willingness to pay for air quality than the rental transaction prices.

Table 13 The Results of Environmental Punishments and Rental Prices

ln *RP*	(1)	(2)
*Near * Post*	0.0034	0.0041
	(0.004)	(0.004)
Post	0.0140***	0.0082***
	(0.003)	(0.003)
Community FE	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	No
Month FE	Yes	No
Year-Month FE	No	Yes
Obs.	44,839	44,839
Adj. R-squared	0.961	0.962

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable is the nature logarithm of rental prices ln *RP* . *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is an indicator variable that equals to one if the housing transaction takes place after the environmental punishment occurs. The focal independent variable *Near * Post* is the interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms and the month dummy variables after environmental punishments occur. We control for the community fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the community level.

To further demonstrate the ex-ante and ex-post effects of environmental punishments on housing rents over time, we apply an event study method. As shown in Figure 7, the environmental punishments solely give rise to the rental prices decline by around 2% at the fourth and fifth months, but do not influence the rental prices in other months. That is to say, the environmental punishments have lagged effects on rental prices.

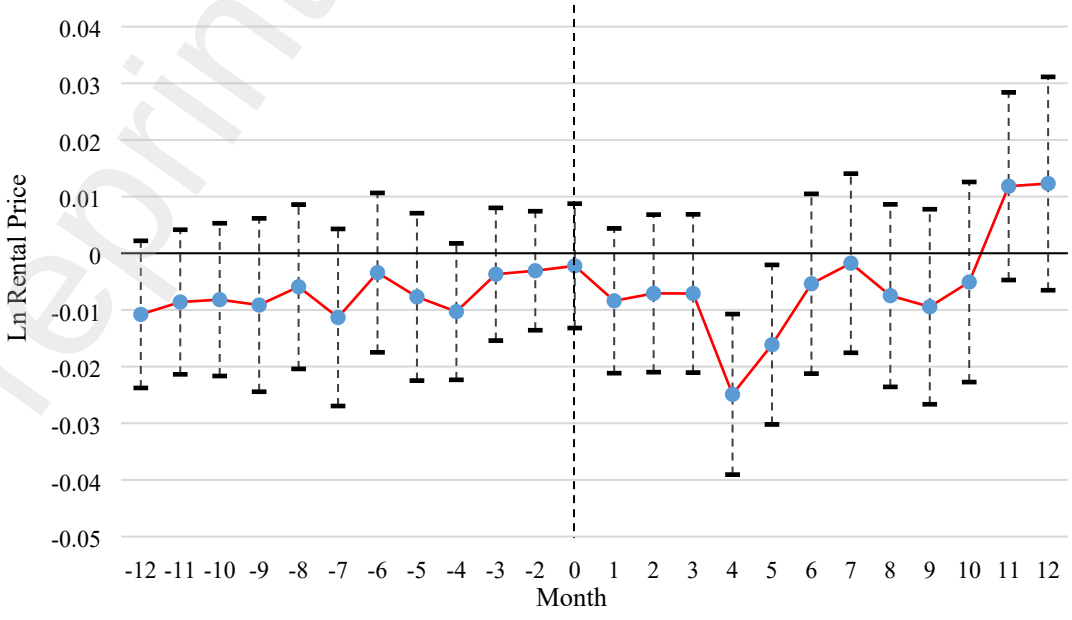

Figure 7. The Event Study on the Effects of Environmental Punishments on Rental Prices

Note: The horizontal axe represents the months before and after the environmental punishments occur. The vertical axe denotes the coefficients of the interaction of treatment dummy variable *Near* and the monthly dummy variables after the environmental punishments occur, dt, on the rental prices. The solid points represent the estimation of coefficients, while the dashed lines delineate 95% confidence intervals.

To capture geographical heterogeneity of environmental punishments on rental prices across locations, we split out sample into inner-city and outer-city by the Fourth Ring Road in Beijing. Generally speaking, renters living in the inner city have greater demand for renting houses than those living in the outer city. Thus, the renters living in the inner city have more rigid demand and weaker responses to the environmental punishments than those living in the outside city. As shown in Table 14, the renters in the inner city pay significantly higher prices than those in the outer city since the environmental punishments occurred. As shown in Colum (2) in Table 14, the renters in the inner city paid 1.74% more than that in the outer city. It suggests that the environmental punishments have greater effects on the rental prices in the outside city than that in the inner city.

Table 14 The Results of Environmental Punishments and Rental Prices in the Inner and Outer Cities

ln *RP*	(1)	(2)
*Near * Post * Inner*	0.0163*	0.0174**
	(0.004)	(0.009)
*Near * Post*	-0.0101	-0.0098
	(0.007)	(0.007)
*Post * Inner*	-0.0439***	-0.0422***
	(0.005)	(0.005)
Post	0.0403***	0.0337***
	(0.004)	(0.004)
Community FE	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	No
Month FE	Yes	No
Year-Month FE	No	Yes
Obs.	44,839	44,839
Adj. R-squared	0.961	0.962

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable is the nature logarithm of housing prices $\ln HP$. The focal independent variable $Near \times Post \times Inner$ is the triple interaction of environmental punishments with the Fourth Ring Road dummy variable. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is an indicator variable that equals to one if the housing transaction takes place after the environmental punishments occur. *Inner* is an indicator variable that equals to one if a community locates inside the Fourth Ring Road in Beijing. We control for the community fixed

effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the community level.

6. Conclusions

The extant literature focuses on the regulatory effects of environmental punishments on housing prices and the deterrent effects of environmental punishments information disclosure, but fails to investigate the outcomes of environmental enforcements from the perspective of information disclosure and dissemination in the short run. This research endeavors to exploits how information disclosure and dissemination of environmental punishments affect housing prices with distance and over time in the short run. Contrary to the conventional wisdom, our results document that the environmental punishments convey bad news rather than good news to the housing market in the short run. In other words, the homebuyers take the environmental punishments as bad news regarding air quality. The results suggest that the housing transaction prices within 0.5 kilometers distance from the environmentally punished firms decrease by 1.84% on average. The overlapping effects of environmental punishments are becoming stronger at the presence of multiple environmental punishments within 0.5 kilometers distance from the traded homes. Moreover, the negative effects of environmental punishments on the housing prices decay with distance and over time. Hence, the environmental punishments could not ameliorate air quality and mainly deliver bad news regarding air quality to the housing markets in the short run. The mechanism of information disclosure indicates that the impacts of environmental punishments on housing price could reinforce if the information is exposed to the public and enhance with the number of online pollution information searching. The mechanism of health concerns verifies that the older homebuyers and younger homebuyers with children respond stronger to the environmental punishments and pay lower housing transaction prices than the unmarried younger homebuyer. We also find the environmental punishments have greater effects on the housing prices in the heating seasons and in the important national political events. For robustness checks, the housing rental markets present little evidence of environmental punishments on the rental prices. Hence, environmental law enforcement mainly plays greater role in housing ownership market than in the housing rental market.

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Appendix

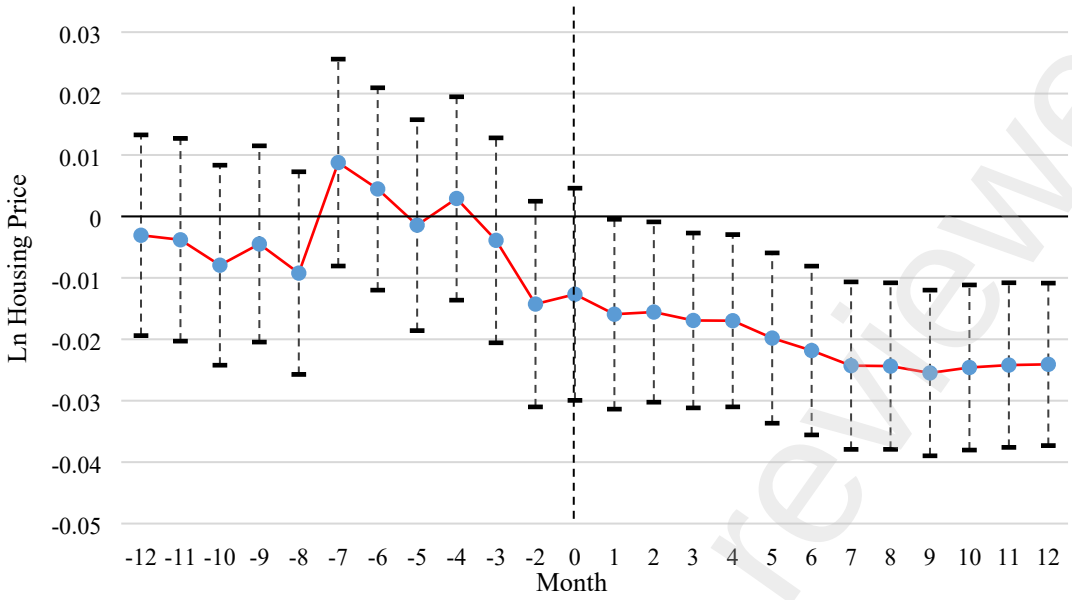

Figure A1 The Cumulative Effects of Environmental Punishments on Housing Price

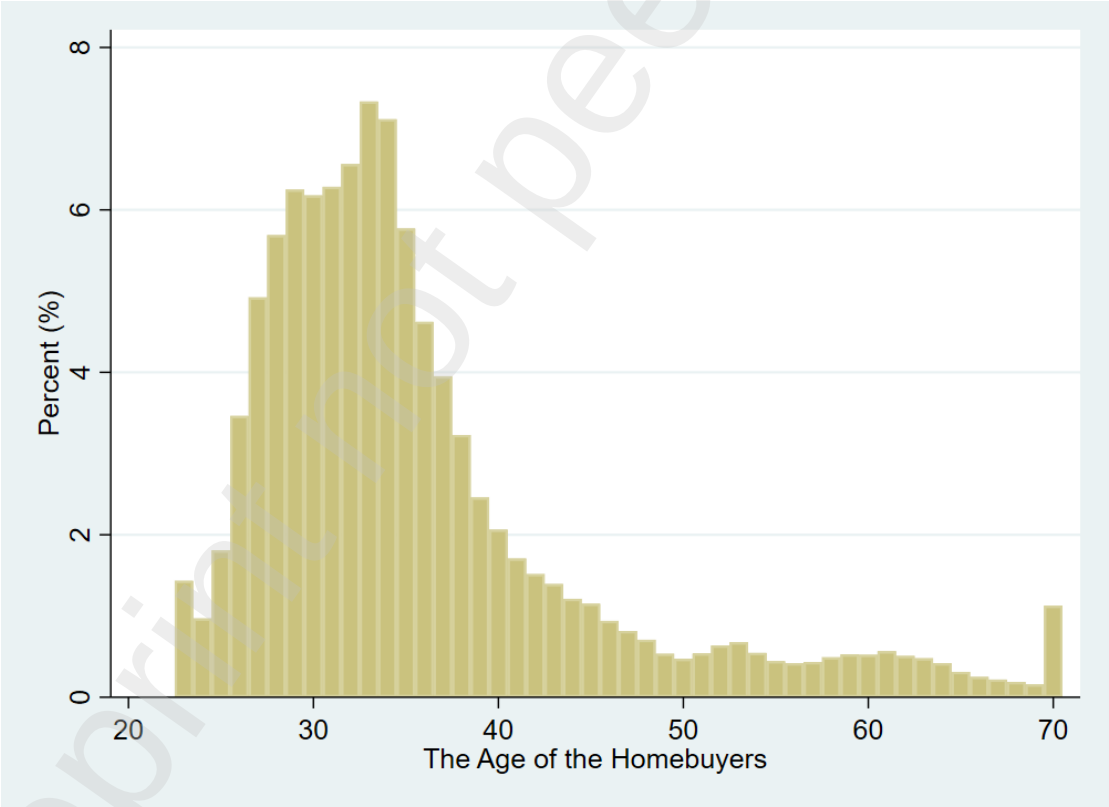

Figure A2 The Distribution of the Homebuyers' Age in our Sample

Table A1 The Distribution of Environmental Punishment Measures in Beijing from January 2015 to December 2017

Month	Daily Fine	Seal and Distrain	Production Reduction and	Administrative Detection	Criminal Offence	Total

		Equipment	Suspense			
201501	0	0	0	0	0	0
201502	0	1	0	0	0	1
201503	0	11	0	0	0	11
201504	0	19	0	0	1	20
201505	2	7	0	0	0	9
201506	0	14	0	0	0	14
201507	1	5	1	1	1	9
201508	0	35	0	0	0	35
201509	1	25	0	0	0	26
201510	0	19	0	0	0	19
201511	0	8	0	0	0	8
201512	0	48	0	0	0	48
201601	0	10	0	0	1	11
201602	0	2	0	0	0	2
201603	0	6	0	0	0	6
201604	0	14	0	0	1	15
201605	0	16	0	0	0	16
201606	0	20	0	1	0	21
201607	0	14	0	0	0	14
201608	0	14	0	0	0	14
201609	0	17	0	0	0	17
201610	2	10	0	0	0	12
201611	1	30	0	0	0	31
201612	0	83	0	0	0	83
201701	0	1	0	0	0	1
201702	2	4	0	1	0	7
201703	0	34	0	1	0	35
201704	0	29	0	0	2	31
201705	1	39	5	1	3	49
201706	0	39	0	1	10	50
201707	0	53	0	3	3	59
201708	0	29	0	1	6	36
201709	1	113	5	2	4	125
201710	0	64	0	0	5	69
201711	0	53	0	0	1	54
201712	2	53	1	0	7	63
Total	13	939	12	12	45	1,021
Portion	1.27%	91.97%	1.18%	1.18%	4.41%	100%

Table A2 The Matching Outcomes of Environmentally Punished Firms in Terms of Firm's Name and Address

Types	Obs.	Percentage
Matched successfully	1021	61.69%

Matched unsuccessfully	551	33.29%
Lack of matching information	83	5.02%
Total	1655	100%

Table A3 The Definition of Key Variables

Variables	Definitions	Metrics
HP	Housing Price	Housing transaction price per square meter in Chinese RMB.
Near	Treatment Groups	A treatment dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms.
Post	Post	An indicator variable that equals to one if the housing transaction takes place after the environmental punishments occur.
Room	Room	The number of rooms.
Hall	Hall	The number of halls.
Toilet	Toilet	The number of toilets.
Fee	Property Management Fee	Property management fee per square meter.
Age	Housing Age	Housing age (years).
Mort	Mortgage	An indicator that equals to one if the housing transaction involves in mortgage
Subw	Subway	An indicator that equals to one if the traded house is close to subway station.
Schl	School	An indicator that equals to one if the traded house is close to school district.
BAge	Homebuyer's Age	Homebuyer's age (years).
SAge	Home-seller's Age	Home-seller's age (years).
BMale	Homebuyer's Gender	An indicator variable that equals to one if the homebuyer is male.
SMale	Home-seller's Gender	An indicator variable that equals to one if the home-seller is male.
Exposed	Exposed Environmental Punishment	An indicator variable that equals to one if the environmental punishment is exposed to the public.
Search	Online Environmental Punishment Searching	The normalized proxy of public online information searching behavior measured by Baidu Search Index.
Old	Old-aged Homebuyers	A dummy variable that equals to one if the homebuyer's age is 41 and above.
Mid	Middle-aged Homebuyers	A dummy variable that equals to one if the homebuyer's age is 31-40.
Closure	Firm's Closure	An indicator that equals to one if the environmental punishments are production

		reduction and suspense, administrative detection or criminal offence.
$PM_{2.5}$	$PM_{2.5}$	The concentrations of $PM_{2.5}$.
PM_{10}	PM_{10}	The concentrations of PM_{10}.
SO_2	SO_2	The concentrations of SO_2.
NO_2	NO_2	The concentrations of NO_2.
O_3	O_3	The concentrations of O_3.
CO	*CO*	The concentrations of *CO*.
Overlap	Overlap	An indictor variable that equals to one if there are two and more environmentally punished firms within 0.5 kilometers distance from the traded houses.
Heat	Heating Season	A dummy variable that equals to one if housing transactions occur in the heating seasons.
Event	Important National Events	A dummy variable that equals to one if housing transactions occur in the important national events.
ln *RP*	Rental Price	The nature logarithm of rental prices.
Inner	Inner City	An indicator variable that equals to one if a community locates inside the Fourth Ring Road in Beijing.

Table A4 The Robustness Results of Environmental Punishments and Housing Prices Within 1 Kilometer Distance From the Environmentally Published Firms

ln *HP*	(1)	(2)	(3)
Near Post*	-0.0122**	-0.0126**	-0.0152***
	(0.005)	(0.005)	(0.005)
Near	-0.0119***	-0.0115***	-0.0101***
	(0.004)	(0.004)	(0.004)
Post	-0.0008	-0.0008	0.0022
	(0.006)	(0.006)	(0.006)
Housing Characteristics	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes
Home-seller Characteristics	No	Yes	Yes
District FE	Yes	Yes	No
Year-Month FE	Yes	Yes	No
District×Year-Month FE	No	No	Yes
Obs.	152,834	152,834	152,834
Adj. R-squared	0.749	0.750	0.754

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. The key independent variables are $Near$, which equals to one if the housing transaction takes place within 1 kilometer distance from the punished firms, and $Post$, which equals to one if the housing transaction takes place after the environmental punishment. The focal independent variable $Near * Post$ is the interaction of the traded houses within 1 kilometer distance from the environmentally published firms and the month dummy variables after environmental punishments occur. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

Table A5 The Results of Environmental Punishments and Housing Prices across Homebuyers' Ages

$\ln HP$	(1)	(2)	(3)	(4)	(5)
$Near * Post * Mid$	-0.0067	-0.0066	-0.0082	-0.0074*	-0.0078*
	(0.006)	(0.006)	(0.006)	(0.004)	(0.004)
$Near * Post$	-0.0246***	-0.0247***	-0.0280***	-0.0172***	-0.0218***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$Near$	-0.0160***	-0.0159***	-0.0136***	-0.0288***	-0.0281***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Post$	0.0005	0.0005	0.0033	0.0002	
	(0.002)	(0.002)	(0.002)	(0.003)	
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District × Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm × Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.760	0.760	0.765	0.844	0.858

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. $Near$ is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. $Post$ is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment. Mid is a dummy variable that equals to one if the homebuyer's age is 45 and above. The focal independent variable $Near * Post * Mid$ is the triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the homebuyer's age is 45 and above. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district × year-month level.

Table A6 The Interactive Effects of Environmental Punishments with Wind Direction on Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Downwind*	0.0066	0.0071	0.0100	0.0042	0.0056
	(0.013)	(0.013)	(0.013)	(0.007)	(0.009)
Near Post*	-0.0290***	-0.0295***	-0.0344***	-0.0205***	-0.0259***
	(0.007)	(0.007)	(0.007)	(0.006)	(0.009)
Near Downwind*	-0.0015	-0.0015	-0.0028	-0.0007	-0.0009
	(0.007)	(0.007)	(0.008)	(0.007)	(0.011)
Post Downwind*	0.0025	0.0022	-0.0022	0.0011	-0.0031
	(0.014)	(0.014)	(0.014)	(0.006)	(0.011)
Near	-0.0152***	-0.0146***	-0.0118**	-0.0285***	-0.0277***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)
Post	-0.0008	-0.0006	0.0044	-0.0003	
	(0.008)	(0.008)	(0.009)	(0.005)	
Downwind	-0.0003	-0.0002	0.0007	-0.0010	0.0012
	(0.004)	(0.004)	(0.005)	(0.003)	(0.006)
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	No
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	Yes
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.762	0.763	0.768	0.844	0.859

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable ln *HP* is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment occurs. *Downwind* is a dummy variable that equals to one if the traded houses locate at the downwind direction of the environmentally punished firms. The focal independent variable *Near* Post* Downwind* is the triple interaction of housing transaction within 0.5 kilometers distance from the punished firms, the month dummy variables after environmental punishments occur and the downwind direction of traded houses. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.

Table A7 The Overlapping Effects of Environmental Punishments on the Housing Prices

ln *HP*	(1)	(2)	(3)	(4)	(5)
Near Post* Punishment*	-0.0151***	-0.0147***	-0.0190***	-0.0315***	-0.0593***

	(0.005)	(0.005)	(0.005)	(0.009)	(0.011)
Near Post*	-0.0072	-0.0079	-0.0062	0.0184*	0.0430***
	(0.008)	(0.008)	(0.008)	(0.011)	(0.014)
Near	-0.0161***	-0.0155***	-0.0133***	-0.0294***	-0.0281***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
Post	0.0005	0.0006	0.0035	0.0008	
	(0.006)	(0.005)	(0.005)	(0.004)	
Housing Characteristics	Yes	Yes	Yes	Yes	Yes
Homebuyer Characteristics	No	Yes	Yes	Yes	Yes
Home-seller Characteristics	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	No	Yes	Yes
Year-Month FE	Yes	Yes	No	Yes	No
District×Year-Month FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	No
Firm×Year-Month FE	No	No	No	No	Yes
Obs.	94,317	94,317	94,317	94,317	94,317
Adj. R-squared	0.760	0.761	0.766	0.844	0.858

Note: ***p<0.01, **p<0.05, *p<0.1. The dependent variable $\ln HP$ is the nature logarithm of housing transaction prices. *Near* is a dummy variable that equals to one if the housing transaction takes place within 0.5 kilometers distance from the punished firms. *Post* is a dummy variable that equals to one if the housing transaction takes place after the environmental punishment. *Punishment* is the number of environmentally punished firms within 0.5 kilometers distance from the traded houses. The focal independent variable *Near* Post* Punishment* is the triple interaction of the traded houses within 0.5 kilometers distance from the environmentally published firms, the month dummy variables after environmental punishments occur and the number of environmentally punished firms within 0.5 kilometers distance from the traded houses. We control for the characteristics of listed housing, homebuyers and home-sellers. We also control for the fixed effects including district fixed effects, punished firm fixed effects and year-month fixed effects. Standard errors in the parentheses are clustered at the district×year-month level.