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Environmental regulation as a double-edged sword for housing markets: Evidence from the NO_x Budget Trading Program ☆

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ABSTRACT

We investigate the effects of environmental regulations on housing markets using a quasi-experimental setting—the NO_x Budget Trading Program (NBP). Hedonic theory predicts that house prices should rise as pollution levels decrease. However, environmental regulations may also affect labor markets, and thus housing demand. Employing a difference-in-differences framework, we find that house prices shifted up in the regulated areas with low manufacturing intensity, whereas in the areas with high manufacturing intensity, housing markets were weakened. We also find that in high-manufacturing-intensity areas, loan application volume declined, rejection rate augmented, and the probability of loan default increased.

1. Introduction

Hedonic theory predicts that house prices should rise as air pollution levels decrease. Extensive empirical evidence has documented the relationship between air quality and housing values.[1] However, another important channel is ignored by the literature: air pollution abatement policies may impose substantial costs to regulated plants and further impact labor markets.[2] The harmful effect on labor markets, e.g., a decrease in employment, may weaken housing demand and further dampen the growth in house prices. Therefore, the answer to the question of how environmental policies influence housing markets can be ambiguous; it depends on both the extent of the improvement of the air quality and the impacts of these policies on the local businesses.

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[1] Some recent papers that study this association include Bayer et al. (2009); Chay and Greenstone (2005); Currie et al. (2015); Kim et al. (2003); Luechinger (2009); and Zheng et al. (2010). The literature has explained the response of house prices to air quality improvement through the channel of health benefits (Chay and Greenstone, 2003; Currie and Neidell, 2005; Deschenes et al., 2012; and Schlenker and Walker, 2015).

[2] A growing body of literature shows that environmental regulations have negative impacts on employment rate, earnings, and total factor productivity, e.g., Curtis (2014); Greenstone (2002); Greenstone et al. (2012); Kahn and Mansur (2013); Walker (2011); and Walker (2013).

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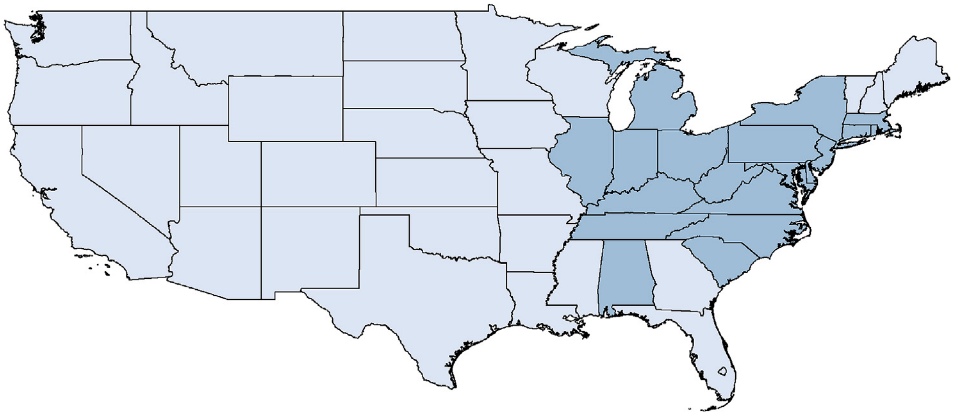


Fig. 1. States covered in the analysis sample. **Note**: Dark-blue states are those participating in the NBP during 2003–2008 (NBP states). Light-blue states did not participate in the program (non-NBP states). In the analysis, we exclude non-NBP states that are adjacent to NBP states, i.e., Arkansas, Florida, Georgia, Iowa, Maine, Mississippi, Missouri, New Hampshire, Vermont, and Wisconsin. Noncontinental states (Alaska and Hawaii) and Puerto Rico are also excluded. See details in data section. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

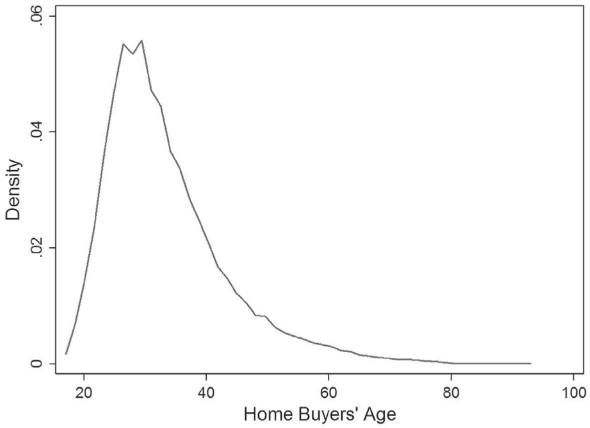
While the literature has focused on the "health channel" of environmental regulations, with positive effects on house prices, we take into account both this health channel and a "labor-market" channel. This factual combination of both channels reveals the heterogeneous effects of air quality regulations on house prices. This paper exploits a quasi-experiment, the NO_x Budget Trading Program (NBP), examining the influence of this cap-and-trade system on the housing markets in the participating regions. The NBP was designed to reduce ozone concentrations in the Eastern region of the U.S. by restricting nitrogen oxides (NO_x) emissions.[3] It was implemented from 2003 to 2008 in nineteen states in addition to Washington, D.C. (see Fig. 1). Deschenes et al. (2012) found that the NBP dramatically reduced NO_x emissions—and thus ozone pollution—in the participating states. Their study also showed that the health benefits, in terms of medication expenditures and mortality rates, were non-negligible as a result of the air quality improvement. However, Curtis (2014) showed that the NBP also imposed substantial costs on manufacturing plants, leading to lower hiring rates and wages, especially for young workers aged between 22 and 34. This age group represents the main force that drives housing demand, as shown in Fig. 2. This quasi-experiment allows us to distinguish between the health channel and the labor-market channel.

We hypothesize that the house prices in NBP regions with high manufacturing intensity were negatively affected by the emission market, as a result of its impacts on the labor markets. However, the housing markets in low-manufacturing-intensity areas benefited from the air pollution abatement. We use data on zip-code-year level house prices from Zillow.com, to study the impacts of the emission market on the house prices. The data are available for more than 10,000 zip code areas in the U.S. and represent more than 95% of the total housing stock by value. To take advantage of the heterogeneity in local business patterns for different counties, we derive industry employment data from the County Business Patterns (CBP) and construct a measure of manufacturing intensity for each county, i.e., the ratio between manufacturing employment and total labor force in 1998.[4]

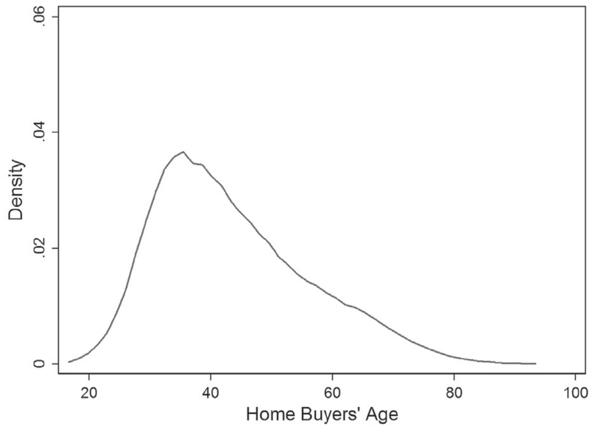
Our analysis is based on a difference-in-differences identification that exploits the variations of the program's time, geographic, and economic characteristics. Our findings are summarized as follows: First, without considering the heterogeneity in local business patterns, the overall effect of the NBP on housing markets in participating states is not statistically significantly different from zero. Fig. 3 illustrates how the NBP affected housing markets in these states. As can be seen, both NBP and non-NBP states shared a similar trend in house prices before 2003. After the market's operation, however, we find that housing markets in NBP states did not gain much as a result of the environmental regulation, in comparison to those in non-NBP states. Second, we find that the effects of the NBP across counties are heterogeneous: house prices in counties with small manufacturing employment proportions are increased, while those in large manufacturing employment proportions are decreased. Specifically, we find that a 1% increase in manufacturing intensity in 1998 statistically significantly reduced the effect of the NBP on house prices by 0.05%. For perspective, house prices in an area in which manufacturing intensity in 1998 was 50% decreased by 5.7%. This estimate implies that the negative impacts of the NBP on labor markets further dampened the growth house prices in high-manufacturing-intensity regions. In contrast, house prices in an area in which manufacturing intensity in 1998 was 5% shifted up by 4.2%. This finding is consistent with the hedoni c theory.

[3] NO_x is a major precursor of ozone formation.

[4] This ratio may be affected by the NBP after the market's initiation; thus, we choose the ratio in 1998 as an exogenous measure of manufacturing intensity.



(a) First-time Buyers



(b) Repeat Buyers

Fig. 2. Age distribution of home buyers before the market's operation. **Note**: Based on data from the American Housing Survey (the national survey) in 1997, 1999, and 2001, the two figures display the age distribution of home buyers before the initiation of the emission market.

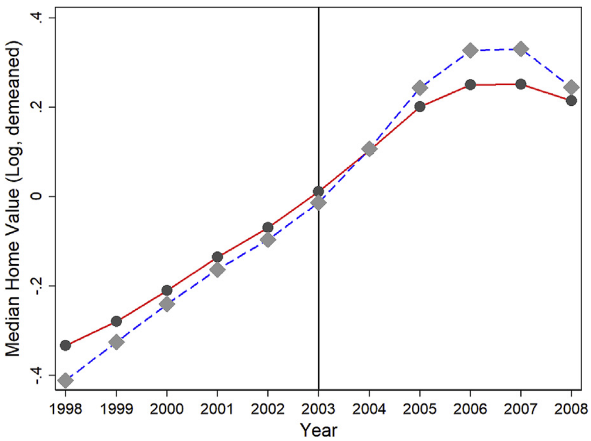


Fig. 3. Average annual house prices in NBP and non-NBP states during the sample period. **Note**: The y-axis is the average log of median home value per square foot (demeaned). The solid red line denotes the average log of median home value per square foot (demeaned) in NBP regions in each year. The dashed blue line represents the average log of median home value per square foot (demeaned) in non-NBP regions in each year. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

To validate the parallel trend assumption of the difference-in-differences estimator, we employ an event-study framework to examine the presence of pre-existing trends. Specifically, we estimate the impacts of the NBP on house prices across years. The coefficients for years before 2003 are not statistically significantly different from zero, suggesting the absence of evidence of clear differences in the trend in house prices between NBP and non-NBP states before the program's operation.

To pin down the labor-market channel, we first use the Home Mortgage Disclosure Act (HMDA) data to investigate how the housing demand was affected in regulated regions. The HMDA is considered the most comprehensive source of mortgage data, covering around 80% of all home loans (Avery et al., 2007). We find that the volume of home loan application statistically significantly decreased in high-manufacturing-intensity areas. In particular, the NBP decreased the application volume in areas with 50% and 40% manufacturing intensity in 1998, by 7.0% and 4.6%, respectively. Interestingly, the NBP also increased the rejection rate for loan applications. The rejection rate in areas with 50% and 40% manufacturing intensity in 1998 was increased by 1.4 and 1.0 percentage points, respectively. This is possibly because lending institutions observed the expectation of the manufacturing sector in regulated areas and thus labeled more applicants in this industry as ineligible ones. These two pieces of evidence indicate that the housing demand was affected by the emission market.

Second, we test whether the environmental policy impacted loan performance by exploiting the BlackBox Logic (BBX) data matched to the HMDA data. To avoid the selection problem, we exclude the loans whose first-month activity in the BBX data was after the policy's initiation. We show that the NBP increased the probability of loan default for individuals in high-manufacturing-intensity areas. This result is consistent with our rationale; the NBP resulted in a higher probability of being unemployed, and thus it led to loan default in these areas. Third, we also rule out an alternative hypothesis, i.e., the heterogeneous effects of the NBP on house prices are a result of the heterogeneous effects of the air pollution abatement. Our results present that the NBP effect on NO_x emissions does not vary by areas with different manufacturing intensities. Fourth, we find that there are limited heterogeneous effects on house prices across other industry intensities or across local demographic characteristics. Fifth, another concern is that the effects on house prices are possibly driven by some random housing supply shocks in the NBP states. We use data on building permits from the Residential Building Permits Survey, to test whether housing supply was affected by the NBP. We find that the NBP effect on housing supply in the NBP states is not statistically significantly different from zero.

We conduct a series of robustness tests. First, as the EPA tightened the National Ambient Air Quality Standards (NAAQS) ozone non-attainment standards in 2004, this policy may bias our estimation. To address this concern, we control the non-attainment status of counties in our regressions. Second, we exclude the Rust Belt states, which are located in the regulated areas, to reduce heterogeneity. The results from these robustness tests are qualitatively and quantitatively similar to those in the main analysis. Third, we examine whether our estimated negative (positive) effects of the NBP on housing prices reflect the international trade shocks to manufacturing industries (the occurrence of housing bubbles) during the 2000s. Our results demonstrate that neither the trade shocks nor housing bubbles in 2000s contribute to our estimates. Lastly, we investigate the NBP effects across house types, which showed to be similar, suggesting that our main results are not driven by a particular type of housing.

Our study makes two contributions to the literature. First, this study provides evidence that environmental policy could negatively impact housing markets due to its adverse effects on labor markets, i.e., the labor-market channel. This adverse effect on housing markets has not been estimated in previous studies. As a result of introducing the emission market, house prices in NBP areas with low (or high) manufacturing intensity increased (or decreased). We quantify the relative importance of the changes in air quality and labor market opportunities caused by the NBP. Second, this is the first study, to our knowledge, that presents the impacts of a large-scale cap-and-trade market on housing markets. Cap-and-trade systems have advantages in terms of efficiency, in comparison to command-and-control style regulations, e.g., NAAQS. Although emission markets provide a market-based solution to abate air pollution, they may also trigger adverse effects (Curtis, 2014). Given the ongoing academic and policy debates on energy sector regulations, fully understanding the impacts of emission markets is important.

The rest of the paper is organized as follows: Section 2 provides a qualitative analysis of NBP impacts on housing markets; Section 3 summarizes our data sources and details the descriptive analysis; Section 4 introduces our empirical framework; Section 5 presents our main findings and sensitivity analyses; and Section 6 concludes.

2. Qualitative analysis

The NBP was a U.S. cap-and-trade system that limited NO_x emissions in eastern states. As NO_x is a key ingredient of ozone formation, the NBP's target was to reduce ozone air pollution.[5] The program began in 2003 and included eight northeastern states in addition to Washington, D.C.[6] In 2004, another 11 states joined the program.[7] The cap-and-trade system only oper-

[5] Details about the NBP market have been documented by Fowlie (2010); Deschenes et al. (2012); and Curtis (2014).

[6] The eight states are Connecticut, Delaware, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and Rhode Island.

[7] The 11 states are Alabama, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, South Carolina, Tennessee, Virginia, and West Virginia. Only a few counties in Alabama and Michigan entered the market. Also, one region in Missouri participated in 2007.

ated from May to September since ozone concentrations are normally high in the summer and low in the winter.[8] According to the U.S. Environmental Protection Agency (USEPA, 2009), 2500 electricity generating units and industrial boilers were enrolled in this cap-and-trade market. Among them, 700 coal-fired plants produced around 95% of the NO_x emissions on the market.

Following Kline (2010), we now develop a partial equilibrium model of housing incidence under the context of pollution emission regulation.[9] The model serves to motivate our empirical strategy. Consider a continuum of workers of measure one who choose one location of two communities $j \in \{M, N\}$ where they will work and demand a single unit of housing. For simplicity, in M all workers work in manufacturing (or polluted) industries, while in N all workers work in non-manufacturing (or non-polluted) industries. Pollution emission regulations (the NBP) are assumed to add costs to plants in the regulated locations.[10] Particularly, residents in regulated locations may lose their job or suffer a wage (w) loss. Residents in each location enjoy location-specific amenities net of any housing costs, A_j. Finally, we allow each individual i to have an idiosyncratic preference for both locations, ϵ_{ij}, representing heterogeneity in the valuation of local amenities. The ϵ_{ij}s are independently and identically distributed across individuals and assumed to possess a continuous multivariate distribution with mean zero.

For individual i, she chooses location j to maximize her utility U_{ij}, given by:

$$U_{ij} = \{v_M + \epsilon_{iM}, v_N + \epsilon_{iN}\}. \tag{1}$$

v_j denotes the average indirect utility in location j. Following Currie et al. (2015), we model $v_j = w_j + A_j$. Individuals will locate in whichever location yields the highest utility. Individuals who locate in M will have $\epsilon_{iN} - \epsilon_{iM} < v_M - v_N$. Denote the distribution function of $\phi_i \equiv \epsilon_{iN} - \epsilon_{iM}$ by $\Phi(\cdot)$. Then, $L_M \equiv Pr(\phi_i < v_M - v_N)$ measures the number of individuals in location M.

Next, we define the aggregate welfare of workers as:

$$V \equiv E[max\{v_M + \epsilon_{iM}, v_N + \epsilon_{iN}\}]. \tag{2}$$

The NBP can be considered a positive amenity shock by restricting air pollution emission in the community. We model this shock as a marginal improvement in air quality in the local community, which is assumed to increase amenities in both M and N equally. The NBP, however, triggered a negative economic shock for the location M through increasing unemployment and decreasing wages.

We then take the derivative of aggregate welfare of workers with respect to the amenity shock associated with the NBP yields the following expression:

$$\frac{dV}{d\lambda} = L_N \cdot \frac{\partial A_N}{\partial \lambda} + L_M \cdot [\frac{\partial A_M}{\partial \lambda} + \frac{\partial w}{\partial \lambda}] = L \cdot \frac{\partial A}{\partial \lambda} + L_M \cdot \frac{\partial w}{\partial \lambda}. \tag{3}$$

$d\lambda$ denotes the marginal effect of the NBP and $\frac{dV}{dV_j} = L_j$. Equation (3) suggests the effect of the NBP may be summarized by two terms. The first term is the total amenity effect associated with the NBP. Since in our empirical application, no evidence indicates that the improvement in air quality is not significantly different across the NBP regions, we assume that the amenity effects are similar in the locations M and N. The second term is the wage effects induced by the NBP for residents who work in the manufacturing industries. As the negative impacts of the NBP on labor markets are mainly for the manufacturing workers, these costs will only accrue to the residents living in M.

To summarize, this framework suggests that the environmental regulation affected the house prices through two channels. First, the air quality improvement increased health conditions. Therefore, people have been willing to pay a higher price to live there. On the other hand, the NBP had negative impacts on the manufacturing employment outcomes, which may trigger a decline in housing markets. After the NBP's initiation, some "marginal" residents in M are better off moving to other places. We hypothesize that the labor-market channel dominates in high-manufacturing-intensity regions, while health channel is critical

[8] In 2004, the NBP operated from June to September.

[9] Our theoretical framework is similar to that in Currie et al. (2015), who also developed the framework from Kline (2010). Our model together with Kline (2010) and Currie et al. (2015) are generalizations of the canonical models of Polinsky and Shavell (1976) and Roback (1982).

[10] The NBP added substantial costs to regulated plants. To comply with the NBP regulations, the regulated plants use several strategies. First, the plants may simply purchase permits to offset emissions that exceed their allocation, without making any change to the production processes. USEPA (2009) showed that around 30% of the regulated firms adopted this strategy. Second, coal-fired plants may switch to cleaner energy sources (e.g., natural gas). Fowlie (2010) documented that few plants changed their energy sources, because cleaner energy sources are much more costly than coal. The third method is to adopt emission control technology. An efficient NO_x control technology, called selective catalytic reduction (SCR), can reduce up to 90% of NO_x emissions. The average cost, however, is about 40 million dollars (Linn, 2008). The last strategy involves reducing the production during regulated months.Although a variety of strategies are available for regulated plants, they all raise the production costs. A number of studies have estimated the cost of the NBP for regulated plants (e.g., Deschenes et al., 2012; Fowlie et al., 2012; Linn, 2010; Shapiro and Walker, 2015). For instance, Deschenes et al. (2012) estimated the annual cost of the NBP to be around 400–700 million dollars. Such high costs forced the plants to employ less labor. Such high costs forced the plants to employ less labor. Using a triple-difference strategy, Curtis (2014) found that the NBP resulted in a 1.3% drop in manufacturing employment and around 4% decrease in new hire earnings. In particular, workers aged 22–34 were affected most. We depict the age distribution of home buyers (first-time and repeat buyers) in Fig. 2, based on data obtained from the American Housing Survey (the national survey) for 1997–2001. Panel (a) describes the age distribution of first-time buyers. In particular, the median age is around 31, and the group of age 22–34 accounts for nearly 60% of the first-time buyers. Around one fourth of the repeated buyers are aged 22–34, as shown in Panel (b). Therefore, the negative impacts of the NBP on the labor market are likely to further induce a decline in demand for housing in NBP states.

in low-manufacturing-intensity regions. The main goal of this paper is to quantify the relative importance of the changes in air quality and labor market opportunities caused by the NBP. We do this by comparing house prices in the high-manufacturing-intensity regions to those in the low-manufacturing-intensity regions. As we assume that both groups are affected similarly by the amenity shock, the difference-in-differences estimate will approximate $\frac{\partial w}{\partial \lambda}$. Our estimates will reflect the aggregate costs/benefits of this cap-and-trade program.

3. Data and descriptive analysis

3.1. Data sources

House prices. Our primary data on house prices at the zip-code-month level come from Zillow.com. Instead of the median sale price, Zillow home value data measure the value of all houses, no matter whether the homes are sold in a given month. The data cover not only single-family homes, but also condominiums and cooperative housing ("co-ops" hereafter). Data are available for more than 10,000 zip code areas and represent more than 95% of the total housing stock by value.[11] Our sample period is from 1998 to 2008 since the NBP was replaced by the Clean Air Interstate Rule (CAIR) in 2008. We mainly use Zillow data, as they are available for many more zip codes relative to Fiserv Case Shiller Weiss (FCSW) index data. Moreover, Zillow data have a good accuracy, as documented by Mian and Sufi (2009). Specifically, they found that the correlation between the Zillow Home Value Index (ZHVI) and the FCSW index reaches 0.91.[12] Zillow provides, in addition to the ZHVI, the median home value per square foot and price indices across house types, including single-family homes, condominiums, and co-ops.

Loan applications and performance. The Home Mortgage Disclosure Act (HMDA), which is considered the most comprehensive source of mortgage data, is implemented by the Federal Reserve Board. Lending institutions are required to report all the data on mortgage applications and originations. This dataset covers around 80% of all home loans (Avery et al., 2007). The HMDA has extensive information on loan characteristics, e.g., geographic location (census tract level), approval status of the application, borrower-reported occupancy status (owner-occupied or investment), and so forth. It also provides detailed borrower characteristics, including the applicant's gender, race, and annual income.

BlackBox Logic (BBX) tracks the monthly performance of each loan. The BBX is one of the most comprehensive sources for mortgage default studies in the U.S. because it aggregates data from mortgage servicing companies (Agarwal et al., 2015). The BBX provides detailed information on loan characteristics and performance, including loan term (30-year, 15-year, etc.), loan type (fixed-rate, 5-1 ARM, etc.), loan purpose (home purchase, rate/term refinance, cash out refinance), occupancy status, and monthly performance (default, prepayment, mature, or current). The outcome variable that we are interested in is whether a loan becomes 60 days or more past due within 24 months following origination.

As the BBX does not contain borrower characteristics, we match the BBX data with the HMDA data using a step-by-step criteria.[13] We first match BBX loans to HMDA loans that have the same loan purpose and occupancy status. Next, based on the origination dates and locations of BBX loans, HMDA loans within the same year and in the same zip code of origination are considered. Last, loans in the BBX are assumed to have the same original loan amount as those in the HMDA. We only keep the first record when one BBX loan has multiple matches from the HMDA, and we exclude all unmatched BBX loans.

Residential building permits. The Residential Building Permits Survey provides statistics on county-year level building permits for new privately owned residential construction.[14] Data are based on reports prepared by local building permit officials in response to a mail survey. The number of new residential building permits is a measure of local housing stock (Quigley and Raphael, 2005). As we discussed above, both air quality improvement and labor market impacts are supposed to influence the demand curve for the housing market, whereas the supply curve should not shift in principle. Examining the NBP effect on housing supply in NBP states serves as a placebo test.

County characteristics. Data on county-year level employment are obtained from the County Business Patterns (CBP) produced by the U.S. Census Bureau. The CBP provides annual economic data by industry for each county, including the number of establishments, employment, and payroll. As our qualitative analysis demonstrates, the impacts of the NBP on house prices may vary by the local manufacturing intensity. We employ this data to create a measurement of manufacturing intensity, i.e., the ratio between manufacturing employment and total labor force in one county. As the ratio may be affected by the NBP after the market's initiation, we select the ratio in 1998 as an exogenous measure of manufacturing intensity for each county. We also generate measurements of other industries' intensity: agriculture, service, and others.[15]

[11] For details, please refer to http://files.zillowstatic.com/research/public/Zillow%20Real%20Estate%20Research%20-%20Why%20We%27re%20Different.pdf.

[12] Guerrieri et al. (2013) provide a detailed comparison of the ZHVI and FCSW indices.

[13] There is no unique common identifier of a loan from these two databases. Our matching procedure is the same as that of An et al. (2016).

[14] Zip-code-level building permits data are not available.

[15] Others include mining, utilities, and construction industry.

Table 1
Descriptive statistics I.

Variables	(1) N	(2) Mean	(3) Std.Dev.	(4) Minimum	(5) Maximum
House prices (zip-code-year level)					
Median home value per square feet (1000$)	92,481	0.13	0.10	0.02	1.12
Home Value Index (1000$)	90,281	219.47	186.74	24.15	3809.13
Single-family HVI (1000$)	89,810	230.78	209.68	24.15	3840.52
Condo HVI (1000$)	36,321	191.13	127.74	27.73	1718.07
Housing supply (county-year level)					
Residential building permits	22,626	904.12	3006.44	1.00	94,700.00
Mortgage (census-tract-year level)					
Mortgage application volume	581,971	378.72	484.39	1.00	27,674.00
Rejection rate (%)	581,971	22.06	12.45	0.00	100.00
County characteristics in 1998					
Manufacturing employment (%)	92,481	17.36	9.41	0.00	61.59
Agricultural employment (%)	92,481	0.24	0.57	0.00	6.44
Service employment (%)	92,481	53.18	9.47	12.81	89.43
Other employment (%)	92,481	29.22	5.43	9.64	86.80
Median age	92,481	35.58	3.03	22.60	47.40
Bachelor's degree or higher (%)	92,481	25.92	9.57	5.60	60.20
College degree (%)	92,481	27.67	4.72	11.80	41.80
High school diploma (%)	92,481	28.54	7.37	11.70	51.10
Less than a high school diploma (%)	92,481	17.87	6.37	3.00	56.60
White (%)	92,481	80.53	14.34	28.50	99.60
African American (%)	92,481	10.22	11.46	0.00	67.90
Asian (%)	92,481	4.00	4.60	0.10	32.60
Other races (%)	92,481	5.97	6.79	0.20	41.10

Note: Median home value per square foot is our main dependent variable in the analysis. The corresponding sample includes 8275 zip codes in 36 states. Other house value indices cover relatively fewer areas. House prices or indices are mean values in each zip-code-year cell. Residential building permits are total values in each county-year cell. Mortgage application volume and rejection rate are total values in each census-tract-year cell. The sample covers the period 1998 through 2008.

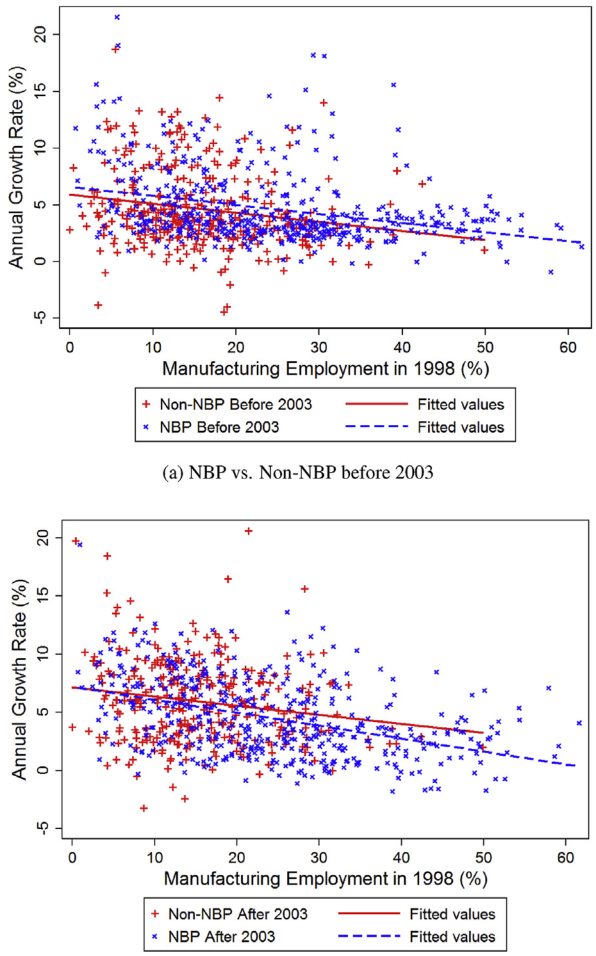
The main source of variation in manufacturing intensity is cross-county differences. Manufacturing intensity may be correlated with other county characteristics that are also determinants of house prices. We obtain the set of potential determinants, including age, educational attainment, and ethnicity, from the 2000 Census. As shown in Table A.1, manufacturing intensity is negatively associated with median age and the percentage of adults with a bachelor's or higher degree, but positively correlated with the percentage of African Americans and adults with a high school diploma.

In our empirical analysis, we do not include Puerto Rico and non-continental states, i.e., Alaska and Hawaii. We also exclude the states that are adjacent to NBP regions, i.e., Arkansas, Florida, Georgia, Iowa, Maine, Mississippi, Missouri, New Hampshire, Vermont, and Wisconsin. These states are excluded because NO_x can be transported downwind for a long distance (Streets et al., 2001), so they may benefit from pollution reduction (Deschenes et al., 2012). Moreover, we do not include the participating counties in Michigan since only a few counties joined the NBP. Sample statistics are summarized in Tables 1 and 2.

Table 2
Descriptive statistics II.

Variables	(1) N	(2) Mean	(3) Std.Dev.	(4) Minimum	(5) Maximum
Default	430,227	0.10	0.30	0.00	1.00
Personal characteristics					
Male	430,227	0.73	0.45	0.00	1.00
White	430,227	0.72	0.45	0.00	1.00
African American	430,227	0.12	0.32	0.00	1.00
Asian	430,227	0.06	0.23	0.00	1.00
Other races	430,227	0.11	0.31	0.00	1.00
Property Type					
Condo	430,227	0.06	0.23	0.00	1.00
PUD	430,227	0.08	0.27	0.00	1.00
Single-Family	430,227	0.86	0.35	0.00	1.00

Note: We use 60 days or more delinquent as our definition of mortgage default. Loans initiated after the NBP's start are excluded. Additionally, observations whose last month activity in the BBX data was before the NBP's initiation are dropped. The sample includes 82,608 unique mortgages.



(a) NBP vs. Non-NBP before 2003

(b) NBP vs. Non-NBP after 2003

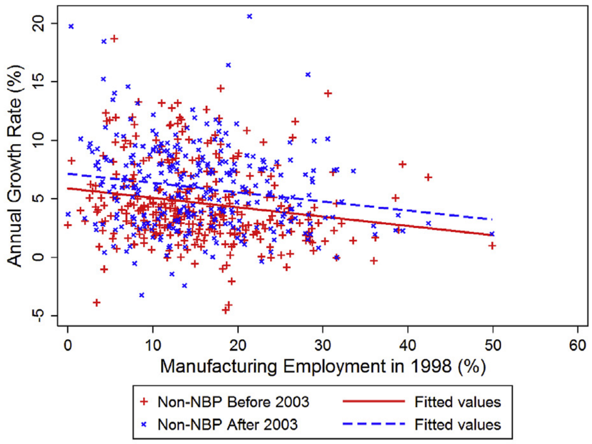
Fig. 4. Manufacturing employment (%) and house price growth rate (%). **Note**: The y-axis in Panels (a) and (b) is average annual house price growth rate in each zip code area in 1998–2002 and 2003–2008, respectively. The x-axis denotes the ratio between manufacturing employment and total labor force in each county in 1998.

3.2. Descriptive analysis

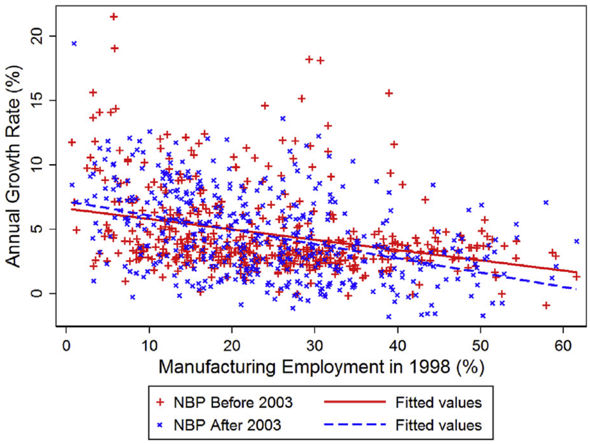
To motivate our empirical analysis, we start by documenting the relationship between annual growth rate of house prices and local manufacturing intensity in 1998. Panel (a) in Fig. 4 displays this relationship for both NBP and non-NBP regions before the market's operation. The linear fitted lines indicate that the larger the percentage of manufacturing employment in 1998, the slower house prices grow. In addition, it is worth noting that the two linear fitted lines are parallel to each other, suggesting that before 2003, both NBP and non-NBP regions shared the similar relationship between the growth rate of house prices and the manufacturing intensity. To compare, Panel (b) in Fig. 4 plots the association after the market's initiation. Interestingly, the two linear fitted lines are no longer parallel to each other. In particular, the slope for NBP regions is steeper than that for non-NBP regions. This difference indicates that after 2003 the gaps in the growth rates of house prices between high- and low-manufacturing-intensity areas significantly widen in NBP states, relative to non-NBP states.

Fig. 5 provides another set of comparisons. In Panel (a), we contrast the same relationship as in Fig. 4 for non-NBP states before and after 2003. The two linear fitted lines demonstrate that the differences in house price growth rate between high- and low-manufacturing-intensity areas remain stable in these regions. However, the slope of the linear fitted line for after 2003 is relatively steeper than that for before 2003, as shown in Panel (b). The comparison in Fig. 5 yields a similar implication as in Fig. 4, i.e., the growth rate of house prices in high-manufacturing-intensity regions of NBP states was dampened after the initiation of the NBP, relative to that in low-manufacturing-intensity areas.

We may interpret the patterns displayed in the two sets of comparisons as the causal effect of emission market-induced negative impacts on the manufacturing labor market. Although air quality improvement is supposed to induce an increase in house prices, the adverse effects of the NBP on manufacturing employment may trigger a decline in demand for housing markets in NBP



(a) Before 2003 vs. after 2003 for Non-NBP



(b) Before 2003 vs. after 2003 for NBP

Fig. 5. Manufacturing employment (%) and house price growth rate (%). **Note**: The y-axis in Panels (a) and (b) is average annual house price growth rate in each zip code area. The x-axis denotes the ratio between manufacturing employment and total labor force in each county in 1998.

states. We acknowledge, however, that our interpretation of these patterns has two major challenges. First, as we documented above, the source of variation in the manufacturing intensity is cross-county differences. High- and low-manufacturing-intensity regions may differ in other unobserved dimensions, which may also explain the differential cross-county growth in house prices. Second, there may exist other policies that were implemented after 2003, which disproportionately affected the housing markets in NBP regions either directly or indirectly. For instance, the EPA released more restrictive ozone non-attainment standards in 2004.[16] These two concerns further motivate our empirical analyses.

4. Empirical strategy

To examine the overall effects of the emission market on house prices, we adopt a difference-in-differences approach. This environmental regulation primarily offers two dimensions of variations in house prices, i.e., before versus after the program's operation and participating versus non-participating states. Exploiting the variations, we estimate the following specification:

$$Y_{it} = \alpha(After_t \times NBP_i) + \mu_i + \lambda_t + \mu_i * t + \mu_i * t^2 + \epsilon_{it}. \tag{4}$$

where the dependent variable is the median home value per square foot (in logarithm) in zip code i in year t. $After_t$ is a dummy variable that equals one after the market's initiation. The variable NBP_i indicates all the areas that participated in the NBP. The interaction term, $After_t \times NBP_i$, is designed to estimate the average effect of the emission market on house prices in NBP

[16] Details are discussed in the results section.

areas. Zip code fixed effects, μ_i, are included to govern any time-invariant zip code level factors. λ_t represents the year fixed effects and captures common shocks over years. To control for nonlinear changes in the determinants of house prices, vectors of the zip-code-specific linear and quadratic time trends, $\mu_i{}^*t$ and $\mu_i{}^*t^2$, are further added. ϵ_{it} represents an idiosyncratic random error term. To adjust for potential temporal and spatial autocorrelations, standard errors are clustered at the state level.[17]

As our qualitative analysis suggests, the sign of β is ambiguous. Specifically, it may be positive because air pollution abatement may induce a housing market boom. However, the negative effects of the NBP on workers in the manufacturing sector may dampen the growth in house prices, especially for manufacturing-dominated areas. To further explore how housing markets in areas with different business patterns were impacted by the cap-and-trade system, we take advantage of the manufacturing-intensity heterogeneity across regions. To achieve this, we employ the following model:

$$Y_{it} = \beta(After_t \times NBP_i \times Manuf_c) + \gamma(After_t \times NBP_i) + \delta(After_t \times Manuf_c) + \mu_i + \lambda_t + \mu_i * t + \mu_i * t^2 + \varepsilon_{it}. \tag{5}$$

where $Manuf_c$ denotes the logged ratio between manufacturing employment and total labor force in county c in 1998.[18] The variable of interest is the three-way interaction, $After_t \times NBP_i \times Manuf_c$, that captures the effects of the NBP on house prices in areas with different manufacturing intensities.

As Curtis (2014) points out, energy-intensity levels are different across manufacturing industries. The NBP may have limited effects on the labor market for areas with a large proportion of low-energy-intensity industries, e.g., electronic product manufacturing, beverage manufacturing, and so forth. Therefore, to take energy-intensity heterogeneity across industry into consideration, we also provide an alternative measurement of the manufacturing intensity. Specifically, we assume that an area with L labor force has m and n workers in M and N manufacturing industry, respectively. The energy-intensities of the two industries are p and q, respectively.[19] Then, the manufacturing intensity for this area is computed as follows: $p \times \frac{m}{L} + q \times \frac{n}{L}$. The correlation between this newly constructed measurement and the original is about 0.53.

Our main hypothesis is that the higher the manufacturing intensity, the more likely labor-market channel on house prices dominates. In other words, we expect the coefficient β to be negative.

4.1. Identification assumption

The validity of this difference-in-differences estimator in our context requires that conditional on the manufacturing intensity level house prices in the NBP and non-NBP regions share a parallel trend before the market's initiation. Fig. 3 presents the median price per square foot in both NBP and non-NBP regions during our sample period. It is evident that before the market's operation, the trends in house prices in the treatment and control groups are parallel. Next, we employ an event-study framework to validate the parallel trend assumption, i.e., estimating the effect of the NBP for each year. The model is as follows:

$$Y_{it} = \sum_{t=1998}^{2008} \zeta_t(NBP_i \times Manuf_c) + \sum_{t=1998}^{2008} \gamma_t(NBP_i) + \delta(After_t \times Manuf_c)\mu_i + \lambda_t + \epsilon_{it}. \tag{6}$$

To implement, we set 2002 as the reference group, i.e., $\zeta_{2002} = 0$. If the coefficients for 1998 through 2001 are not statistically significantly different from zero, this may imply that there is no evidence of clear differences in the trends in house prices between NBP and non-NBP states before 2003 conditional on the manufacturing intensity level. In addition to checking the common trend assumption, this method enables us to estimate the policy effect for each year after the market's initiation.

One potential flaw in this method is that it requires large samples to get the precisely estimated effect for each year; Otherwise, the reported insignificant effects may be due to the lack of statistical power. To overcome this problem, we employ the following specification to double check the common trend assumption:

$$Y_{it} = \rho(NBP_i \times Manuf_c \times t) + \mu_i + \lambda_t + \xi_{it}. \tag{7}$$

The notations are the same as those in Equation (5). Using the data from 1998 to 2002, we test whether there is a significantly different pre-trend in house prices between the NBP and non-NBP states conditional on the manufacturing intensity level. The null hypothesis is $\rho = 0$. Standard errors are clustered at the state level.

[17] We also try the spatial clustering, i.e., adjusting standard errors to account for the potential that disturbances have spatial autocorrelation of arbitrary form within 2000 km and serial correlation over three years (Hsiang, 2010). Our inferences change slightly. The results are upon request.

[18] One may question the particularity of the measurement in 1998. In robustness checks, we replace it with the average logged ratio between 1998 and 2002. As shown in Table A.2, our main conclusions remain stable. Additionally, there are a few counties with no manufacturing intensity (less than 1%). To account for this, we use a transformation with a logarithm of manufacturing employment percentage plus one.

[19] Energy expenditure data across industries are derived from the NBER Productivity Database. Following Curtis (2014), energy intensity is the ratio between total industry energy expenditure and total value of shipments for one industry.

Table 3
Overall impact of the NBP on house prices.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP	−0.061	0.004	0.004	−0.007
	(0.085)	(0.039)	(0.040)	(0.040)
Observations	92,481	92,481	92,481	92,481
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After* × *NBP* is the differences-in-differences estimator, which equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

5. Main results

In this section, we begin by reporting the overall effect of the NBP on housing markets in participating states. We then present the NBP effects across counties with different manufacturing intensities, which are the central findings of this paper. The next section discusses the possible mechanisms. In the last part, we conduct a series of sensitivity analyses.

5.1. Overall effect of the NBP

Before the regression analysis, Fig. 3 presents a visual depiction of how house prices in participating states were affected by the cap-and-trade market. Before the market's operation, the trends in house prices in NBP and non-NBP states are relatively parallel. After 2003, however, house prices in NBP regions seem to grow slower than those in non-NBP regions, indicating that housing markets in the NBP regions did not benefit much from the pollution abatement program.

Table 3 reports statistical estimates of the overall effect of the NBP on median price per square foot. In column (1), we control for zip code and year fixed effects; the coefficient is negative, but not statistically significantly different from zero. In column (2), we add county-specific linear trends to the regression. As can be seen, the magnitude of the coefficient becomes smaller, and the confidence interval is quite large. In column (3), we replace county-specific linear trends with zip-code-specific linear trends. The coefficient remains stable. In column (4), we further add the zip-code-specific quadratic trends to the regression. Again, the coefficient demonstrates that the overall effect of the NBP on house prices is not significantly different from zero. To sum up, both Fig. 3 and Table 3 suggest that the housing markets in NBP states did not gain much due to the emission market, in comparison to those in non-NBP states.

5.2. Heterogeneous effects by manufacturing intensity

Table 4 presents estimates of several versions of Equation (5). Column (1) is our most parsimonious specification; it only includes two variables of interest and zip code and year fixed effects. The sign of the coefficient on *After* × *NBP* indicates that the NBP effect on house prices in NBP areas with no manufacturing employment in 1998 was positive. On top of that, the coefficient on *After* × *NBP* × *Manuf* is statistically significantly negative, suggesting that the higher the manufacturing intensity, the more house prices were negatively affected by the NBP. These results seem to be consistent with our main hypothesis. To partial out potentially different trends in the determinants of house prices, we add county- and zip-code-specific linear trends in columns (2) and (3), respectively. Coefficients in columns (2) and (3) are smaller than those in column (1) but remain statistically significant at the conventional level. Column (4) is our richest specification, which further controls the zip-code-specific quadratic trends. The estimates are similar to those in columns (2) and (3). The coefficient on the three-way interaction indicates that a 1% increase in manufacturing intensity in 1998 reduced the effect of the NBP on house prices by around 0.05%.

Next, we use concrete examples to interpret our estimates in column (4). For NBP regions with 50%, 40%, and 30% manufacturing intensity in 1998, this cap-and-trade program decreased the house prices by 5.7%, 4.7%, and 3.4%, respectively.[20] On

[20] The figures are computed as follows: $5.7\% \approx (0.124 + (-0.046) \times \log(50 + 1)) \times 100\%$; $4.7\% \approx (0.124 + (-0.046) \times \log(40 + 1)) \times 100\%$; $3.4\% \approx (0.124 + (-0.046) \times \log(30 + 1)) \times 100\%$.

Table 4
Impact by areas with different manufacturing intensities.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.122***	−0.043***	−0.043***	−0.046***
	(0.029)	(0.013)	(0.013)	(0.017)
After × NBP	0.291***	0.126**	0.127**	0.124**
	(0.096)	(0.059)	(0.062)	(0.060)
After × Manuf	−0.052**	−0.025*	−0.025	−0.015
	(0.026)	(0.014)	(0.015)	(0.014)
Observations	92,481	92,481	92,481	92,481
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

the other hand, the house prices in districts with 10% and 5% manufacturing intensity in 1998 rose by 1.4% and 4.2%, respectively. These calculations assume a specific functional form of the effect of manufacturing intensity. To relax the functional form assumption, Table A.3 presents nonparametric estimates. Specifically, we examine the NBP effect on regions with manufacturing intensity in 1998 less than 5%, 5–10%, 10–15%, 15–40%, 40–45%, 45–50%, and more than 50%. In column (1), we control zip code and year fixed effects and county-specific linear trends. House prices in areas with the lowest and highest manufacturing intensity were statistically significantly affected. Additionally, nonparametric estimates display a monotonic pattern. Specifically, NBP effects on house prices for these seven groups are 6.1%, 3.0%, 3.7%, −1.8%, −2.5%, −3.2%, and −5.2%, respectively. In columns (2) and (3), we find that the monotonic pattern is robust, by adding the zip-code-specific linear and quadratic trends.

As Curtis (2014) points out, energy-intensity levels are different across manufacturing industries. The NBP regulated about 2500 electricity generating units and industrial boilers, which were mostly in the energy-intensive industries. Therefore, we expect that the NBP may have limited effects on the labor market for areas with a large proportion of low-energy-intensity industries, e.g., electronic product manufacturing, beverage manufacturing, etc. To take this issue into account, we construct another measurement of manufacturing intensity. Specifically, we assume that an area with L labor force has m and n workers in M and N manufacturing industry, respectively. The energy-intensities of the two industries are p and q, respectively.[21] Then, the manufacturing intensity for this area is computed as follows: $p \times \frac{m}{L} + q \times \frac{n}{L}$. The correlation between this newly constructed measurement and the original is about 0.53.

Estimates using this measurement are reported in Table 5. They demonstrate that our main conclusions do not change much. Specifically, as shown in column (3), the three-way interaction demonstrates that a 1% rise in manufacturing intensity in 1998 reduced the effect of the NBP on house prices by 0.04%, which is comparable to that in Table 4. We conduct a Chow-test between column (4) in Tables 4 and 5. The p-value is 0.41, which indicates that we cannot reject the null hypothesis, i.e., the coefficients on the three-way interaction in the two regressions are equal to each other. All the results below are similar by using these two measurements. For the sake of interpretation, in the following analyses we mainly use the former measurement on manufacturing intensity.

Identification assumption test. We adopt an event-study framework to examine the presence of trends in advance of the market's operation. Using Equation (6), we can estimate the NBP effect on house prices in each year. The estimates are plotted in Fig. 6. We set 2002 as the reference group, i.e., the coefficient on 2002 is zero. As can be seen, all of the coefficients in the period of 1998–2001 are close to zero and not statistically significant at the traditional level. This indicates the presence of only a slight pre-existing trend between NBP and non-NBP states. Additionally, Fig. 6 illustrates the NBP effect on house prices after 2003. Noticeably, the coefficients are all negative after the market begins to operate, varying between 0 and -0.05. Their absolute magnitudes gradually become larger from 2003 to 2007. This pattern indicates that our estimates in Table 4 are not driven by effects that arise from a specific year. Furthermore, this pattern is similar to that shown by Curtis (2014). The magnitude of NBP effects on labor markets gradually became larger after 2003, and slightly decreased after 2006. The consistent patterns support our contention that the negative effects on housing markets come from the NBP effects on labor markets.

One potential flaw in this method is that it requires large samples to get the precisely estimated effect for each year; Otherwise, insignificant effects may be due to the lack of statistical power. To overcome this problem, we employ Equation (7) to

[21] Energy expenditure data across industries are derived from the NBER Productivity Database. Following Curtis (2014), energy intensity is the ratio between total industry energy expenditure and total value of shipments for one industry.

Table 5
An alternative measurement of manufacturing intensity.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf Energy	−0.099***	−0.036***	−0.036***	−0.038***
	(0.032)	(0.010)	(0.011)	(0.011)
After × NBP	0.289***	0.132***	0.132***	0.128***
	(0.096)	(0.026)	(0.027)	(0.037)
After × Manuf	0.051*	0.024*	0.024*	0.019
	(0.027)	(0.014)	(0.014)	(0.013)
Observations	92,481	92,481	92,481	92,481
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *ManufEnergy* is the logged ratio between manufacturing employment and total labor force in each county in 1998, weighted by energy intensity of each industry. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

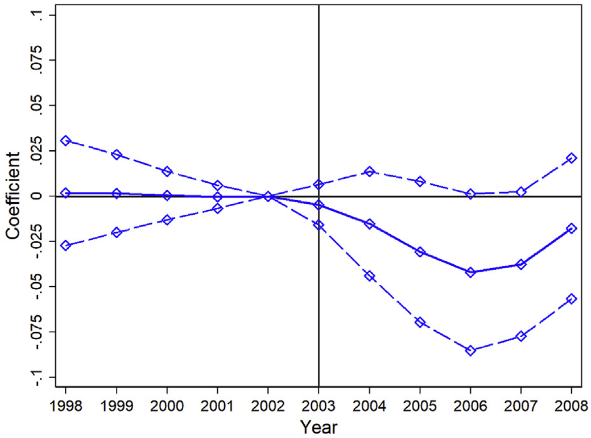


Fig. 6. NBP effect across years. **Note**: Solid lines denote estimated coefficients. Dashed lines represent upper and lower bounds for the 95% confidence interval.

double check the common trend assumption. As shown in Table 6, the estimate on the pre-existing differences between NBP and non-NBP states before 2003 are far from statistically significant, consistent with the results in event studies.

5.3. Mechanisms

Loan applications and performance. We hypothesize that the negative effect of the NBP on labor markets in high-manufacturing-intensity areas should weaken local housing demand, which further leads to a declination in house prices. To test this hypothesis, we examine whether loan applications and performance were affected by the NBP.

We aggregate HMDA data to the census-tract-year level. Our outcome variables are the loan application volume and rejection rate. We use Equation (5) to estimate the impacts. As shown in column (3) in Table 7, the coefficient on the three-way interaction indicates that a 1% increase in manufacturing intensity in 1998 reduced the effect of the NBP on application volume by 0.1%. We discuss some examples to render our estimates more interpretable. For areas with 50% and 40% manufacturing intensity in 1998, the NBP decreased their application volume by 7.0% and 4.6%, respectively. For districts with 10% and 5% manufacturing intensity in 1998, their application amount shifted up by 10.1% and 16.9%, respectively.

As shown in column (6) in Table 7, the three-way interaction is positive and statistically significant at the 1% level. The NBP increased the rejection rates in areas with 50% and 40% manufacturing intensity in 1998 by 1.4 and 1.0 percentage points, respectively. Meanwhile, the rejection rates in districts with 10% and 5% manufacturing intensity in 1998 decreased by 1.1 and 2.1 percentage points, respectively. These results suggest that the lending institutions may observe the expectation of the manufacturing sector in regulated areas and thus label more applicants in this industry as ineligible ones.

Next, we test whether the environmental policy impacted loan performance, by exploiting the BBX data matched to the HMDA data. Our dependent variable is a dummy that equals one if a loan is 60 days or more past due within the 24 months

Table 6
Validity checks on the identification assumption for the difference-in-differences estimator.

VARIABLES	(1) Logged Median Price Per Sqr Ft
NBP × Manuf × year	−0.005
	(0.005)
Observations	41,644
R-squared	0.98
Zip Code FE	Yes
Year FE	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). NBP × Manuf × year is the interaction between a NBP-region dummy, local manufacturing intensity, and linear trend term. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table 7
Impact on loan application volume and rejection rate.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Logged Mortgage Application Volume			Rejection Rate (%)		
After × NBP × Manuf	−0.140***	−0.103*	−0.112*	1.051	1.360***	1.610***
	(0.044)	(0.057)	(0.060)	(0.629)	(0.421)	(0.435)
After × NBP	0.465***	0.360*	0.370*	−3.463**	−4.212***	−4.941***
	(0.147)	(0.202)	(0.208)	(1.666)	(1.540)	(1.595)
After × Manuf	−0.035	−0.061	−0.062	0.245	−0.401	−0.542**
	(0.040)	(0.061)	(0.063)	(0.324)	(0.260)	(0.265)
Observations	581,968	581,968	581,968	581,968	581,968	581,968
R-squared	0.22	0.24	0.24	0.28	0.30	0.31
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	Yes	No	Yes	Yes
County Quadratic Trend	No	No	Yes	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable in columns (1) and (2) is the number of mortgage applications (in logarithm) and rejection rate in each census tract in each year. *After × NBP* equals 1 for all areas belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

following origination. The results in Table 7 indicate that the NBP affected the mortgage application volume and the rejection rate. Therefore, after the policy's initiation, the individuals whose applications were approved may not be comparable between participating and non-participating states. To avoid this selection problem, we exclude the loans whose first-month activity in the BBX data was after the policy's initiation as well as those whose last-month activity in the BBX data was before the policy's initiation. These loans are assumed to be unaffected by the policy.

Column (3) in Table 8 presents the estimates using Equation (5). In column (4), we further add borrower characteristics as controls, including gender, race, and property type dummies. The coefficient on the three-way interaction term indicates that the NBP did increase the probability of loan default for individuals in high-manufacturing-intensity areas. Specifically, a 1% increase in manufacturing intensity in 1998 increased the effect of the NBP on loan default risk by 0.02 percentage points.

Electricity prices. The NBP includes around 700 coal-fired electricity generating units. With the increase in the costs of NO_x emissions, it is reasonable to expect that NBP would drive up electricity prices. If so, firms may have to adjust their input bundles by decreasing employment in response to an increase in electricity prices or the uncertainty about the future electricity prices. Testing the spatial changes in electricity prices is critical for the validity of our labor market channel.

Our electricity price data are constructed from the Energy Information Administration (EIA) form 861. Following Kahn and Mansur (2013), we compute the electricity price by first aggregating revenue from industrial customers at any utility that serves these customers in a given county and year. Then we divide this industrial revenue by the quantity of electricity sold to industrial customers by those utilities in that year. In the analysis, we replace the dependent variable in our Equation (5) with electricity prices (in logarithm) at the county-year level. Table 9 presents the estimates. These results are consistent with our expectation. The coefficients of the three-way interaction in columns (1) and (2) indicate that the larger the manufacturing intensity, the more electricity price increased. Column (3), our richest specification, indicates that a 1% increase in manufacturing intensity in 1998 increased the effect of the NBP on electricity prices by 0.016%. For NBP regions with 50%, 40%, and 30% manufacturing intensity in 1998, this cap-and-trade program increased electricity prices by 1.9%, 1.5%, and 1.1%, respectively. These results provide us another support for the labor market channel.

Table 8
Impact on loan performance.

VARIABLES	(1) Default Dummy	(2)	(3)	(4)
After × NBP × Manuf	0.027**	0.021***	0.021***	0.021***
	(0.011)	(0.008)	(0.008)	(0.008)
After × NBP	−0.033	−0.032	−0.032	−0.032
	(0.038)	(0.024)	(0.024)	(0.024)
After × Manuf	−0.004	0.002	0.002	0.001
	(0.014)	(0.006)	(0.006)	(0.006)
Male				−0.012***
				(0.002)
White				−0.027***
				(0.009)
African American				0.042***
				(0.006)
Asian				−0.027***
				(0.009)
Single-family				0.018***
				(0.006)
PUD				−0.002
				(0.003)
Observations	430,227	430,227	430,227	430,227
R-squared	0.07	0.08	0.08	0.08
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	Yes	Yes
County Quadratic Trend	No	No	Yes	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is a dummy indicating whether an individual defaulted on loans in each year. *After × NBP* equals 1 for all individuals belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. The sample includes three property types, i.e., condo (reference group), single-family, and planned unit development (PUD). Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Pollution emissions. One may question whether the heterogeneous effects of the NBP on house prices are a result of the heterogeneous effects of air pollution abatement. For perspective, pollution emissions may be reduced to a larger extent in low-manufacturing-intensity areas as compared to emissions in high-manufacturing-intensity areas. Additionally, pollution emissions in high-manufacturing-intensity areas may somehow go up after the emission market's initiation, which can explain the negative impacts of the NBP on house prices in those areas. In essence, Table A.4 tests this idea. In column (1), the coefficient indicates that NO_x emissions in the NBP operating period (summertime) in NBP states decreased by around 13.8%. Estimates in columns (2) and (3) suggest that the NBP effect on NO_x emissions do not vary by areas with different manufacturing intensities.

Table 9
Impact on the electricity price by areas with different manufacturing intensities.

VARIABLES	(1) Electricity Price (in logarithm)	(2)	(3)
After × NBP × Manuf	0.014**	0.015**	0.016**
	(0.006)	(0.006)	(0.006)
After × NBP	−0.018	−0.044	−0.044
	(0.025)	(0.029)	(0.029)
After × Manuf	−0.011***	−0.019***	−0.019***
	(0.003)	(0.007)	(0.007)
Observations	24,770	24,770	24,770
R-squared	0.95	0.96	0.96
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	Yes
County Quadratic Trend	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a county-year cell. The dependent variable is the electricity price (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table 10
Do nonmanufacturing industries matter?.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP	−0.003	−0.258*	−0.230*	
	(0.038)	(0.151)	(0.115)	
After × NBP × Manuf				−0.044***
				(0.016)
After × Manuf				0.014
				(0.040)
After × NBP × Agriculture	−0.023			−0.001
	(0.039)			(0.035)
After × Agriculture	0.018			0.035
	(0.030)			(0.034)
After × NBP × Service		0.063		−0.013
		(0.039)		(0.018)
After × Service		0.081**		0.117
		(0.031)		(0.106)
After × NBP × Others			0.067*	0.051*
			(0.037)	(0.026)
After × Others			−0.033	−0.010
			(0.026)	(0.053)
Observations	92,481	92,481	92,481	92,481
R-squared	0.99	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Zip Code Linear Trend	Yes	Yes	Yes	Yes
Zip Code Quadratic Trend	Yes	Yes	Yes	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf*, *Agriculture*, *Service*, and *Others* are the logged ratio between manufacturing, agricultural, service, and other employment and total labor force in each county in 1998, respectively. *Others* includes mining, utilities, and construction employment. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

In other words, NO_x emissions were consistently reduced in NBP states. Therefore, our findings cannot be explained solely by the air pollution abatement.

Nonmanufacturing industries. As the NBP mainly decreased employment and earnings in the manufacturing sector, house prices should not be affected by the interactions between the NBP and other industry intensities. Columns (1) through (3) in Table 10 examine whether the proportion of agricultural, service, and other industry employment in 1998 plays an important role in determining house prices.[22] As can be seen, coefficients on the three-way interactions in these columns are not statistically significant at the 5% level. In column (4), we simultaneously control all the three-way interactions in the regression. The coefficient on the interaction with manufacturing intensity remains stable and is statistically significant at the 1% level. Interactions with agricultural and service industry intensities are not statistically significant, whereas those with other industry intensities are positive and marginally statistically significant.

Other related characteristics. The correlations shown in Table A.1 between manufacturing intensity and other county characteristics of age, education, and ethnicity raise a concern as to whether we are capturing the causal effect of manufacturing intensity or differential trends in house prices in less educated, younger, and high-minority areas. To address this question, we directly control interactions between *After × NBP* and other county characteristics. Notably, as shown in Table 11, the coefficient on *After × NBP × Manuf* remains stable, while most coefficients on other three-way interactions are not statistically significantly different from zero.[23] We use the Wald test to check whether the summation of all other interactions is equal to zero. The p-value in column (4) is 0.44, respectively, based on which we cannot reject the null hypothesis. By and large, including these controls does not influence the magnitude or significance of the coefficient on manufacturing intensity.

Housing supply. The effect of the NBP on housing markets is assumed to come from the demand side: either labor market effects or air quality improvement shifts the demand curve for housing markets in NBP states. However, the supply curve should not shift as a result of the emission market. Using data on residential building permits, we examine the NBP effect on housing supply in NBP states. Table 12 reports the corresponding estimates. The statistically insignificant coefficients in column (3) indicate that the supply curve in NBP areas was not affected.

[22] The industry division is based on the North American Industry Classification System (1997). Other industries include mining, utilities, and construction.

[23] The coefficient on *After × NBP* is no longer comparable to that in column (3) in Table 4. The coefficient in Table 11 represents the NBP effect on house prices for areas with all characteristics equal to zero.

Table 11
Do other population characteristics matter?.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.115***	−0.041***	−0.041***	−0.042***
	(0.032)	(0.013)	(0.014)	(0.015)
After × NBP × Median Age	0.325*	0.142	0.142	0.139
	(0.188)	(0.125)	(0.131)	(0.155)
After × NBP × Bachelor and above	0.197**	0.022	0.021	−0.032
	(0.093)	(0.056)	(0.058)	(0.062)
After × NBP × College	−0.033	0.101	0.102	−0.032
	(0.212)	(0.121)	(0.127)	(0.107)
After × NBP × High School	0.161	−0.052	−0.052	−0.045
	(0.151)	(0.091)	(0.095)	(0.097)
After × NBP × Less than High School	0.006	−0.001	−0.001	−0.005
	(0.008)	(0.003)	(0.004)	(0.004)
After × NBP × White	−0.039	−0.112	−0.112	−0.120
	(0.174)	(0.091)	(0.095)	(0.078)
After × NBP × African American	−0.041	−0.041**	−0.041**	−0.040**
	(0.038)	(0.016)	(0.016)	(0.015)
After × NBP × Asian	0.002	−0.019	−0.019	−0.003
	(0.022)	(0.014)	(0.015)	(0.014)
Observations	92,481	92,481	92,481	92,481
R-squared	0.97	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Due to space limitations, two-way interactions between *After* and other characteristics are omitted. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table 12
NBP impact on residential building permits.

VARIABLES	(1)	(2)	(3)
	Logged Residential Building Permits		
After × NBP × Manuf	0.045	−0.038	−0.050
	(0.045)	(0.031)	(0.034)
After × NBP	−0.284**	0.111	0.138
	(0.135)	(0.100)	(0.115)
After × Manuf	−0.045	0.040	0.029
	(0.040)	(0.032)	(0.031)
Observations	22,746	22,746	22,746
R-squared	0.94	0.96	0.97
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	Yes
County Quadratic Trend	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is logged residential building permits in a county-year cell. *After × NBP* equals 1 for all counties belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

5.4. Sensitivity analysis

NAAQS non-attainment status. In 2004, the EPA tightened NAAQS ozone non-attainment standards, i.e., areas that did not satisfy the 1997-standard 8-h ozone areas were identified. As a result, more than 400 counties were assigned to non-attainment status. As demonstrated above, most of these non-attainment counties were concentrated in NBP regions. Additionally, a strand of literature has provided convincing evidence that NAAQS attainment standards have negative impacts on labor markets. Therefore, the policy shock in 2004 may create different effects on house prices in NBP regions. To tackle this concern, we add the interaction between the *After × NBP* and non-attainment status in 2004 to Equation (5).

Table 13
NAAQS regulations.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.118***	−0.045***	−0.045***	−0.047**
	(0.028)	(0.011)	(0.012)	(0.018)
After × NBP	0.315***	0.135***	0.136***	0.129*
	(0.095)	(0.046)	(0.048)	(0.064)
After × Manuf	−0.037*	−0.010	−0.010	−0.003
	(0.019)	(0.009)	(0.009)	(0.011)
After × NBP × Non-att	−0.119*	−0.042*	−0.042*	−0.034
	(0.068)	(0.023)	(0.024)	(0.025)
After × Non-att	0.206***	0.121***	0.121***	0.097***
	(0.068)	(0.030)	(0.032)	(0.029)
Observations	92,481	92,481	92,481	92,481
R-squared	0.97	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. $Non - att$ is a dummy variable that equals one if a county failed to meet NAAQS ozone non-attainment standards in 2004 through 2008. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table 13 statistically summarizes estimates based on the new specification. In column (4), the coefficient on the three-way interaction with non-attainment status is not statistically significant at the traditional level. More importantly, the coefficients on the manufacturing intensity interaction remain stable compared to those in Table 4. The comparison demonstrates that including these controls in the regressions does not have a significant influence on our main results.

Rust Belt states. Rust Belt states, which include Illinois, Indiana, Michigan, Ohio, and Pennsylvania, have experienced an economic decline and population loss for decades (e.g., Glaeser and Gyourko, 2005). As these states are all in NBP regions, their particularities may potentially drive our estimated treatment effects. In regressions, we already control for zip-code-specific linear and quadratic trends, which may partly address this concern. To further reduce heterogeneity, we exclude these Rust Belt states from our regression sample. Table 14 presents estimates based on the new sample. In column (4), the three-way interaction indicates that a 1% rise in manufacturing intensity in 1998 reduced the effect of the NBP on house prices by 0.06%, which is slightly larger than that in Table 4, and is statistically significant at the 1% level. Therefore, our main conclusions are insensitive to excluding Rust Belt states.[24]

Exposure to Chinese import penetration. During our sample period (1998–2008), manufacturing employment in the U.S. fell around 30%. David et al. (2013) found that rising imports from China cause higher unemployment, lower labor force participation, and reduced wages in local labor markets that house import-competing manufacturing industries. Many of the areas that affected by the changes in trade were the industrial regions of the southeast and midwest where the NBP was implemented. Consequently, one may concern that our estimated negative effects of the NBP on housing prices reflect the trade shocks to manufacturing industries during the 2000s. To assuage this concern, we add the interaction between the *After × NBP* and exposure to Chinese import penetration in 2000 to Equation (5). The measurements on exposure to Chinese import penetration in 2000 are obtained from David et al. (2013).

Table 15 displays the corresponding results. As can be seen in column (4), the coefficient on the three-way interaction with exposure to Chinese import penetration is not statistically significant at the conventional level. Additionally, the coefficients on the manufacturing intensity interaction remain stable compared to those in Table 4. The results indicate that our estimated negative effects of the NBP on housing prices do not reflect the trade shocks to manufacturing industries during the 2000s.

Housing bubble. Our sample period also coincides with the occurrence of the housing bubble in the U.S. The magnitude of the housing bubble varied substantially across regions. Of particular concern for our study, the housing bubble was larger in areas with low manufacturing intensity, partially reflecting the positive correlation of manufacturing employment with the elasticity of local housing supply (Howard et al., 2017). Consequently, one may concern that our estimated positive effects of the NBP on housing prices reflect the housing bubbles during the 2000s. To solve this problem, we add the interaction between the

[24] People may also concern the particularity of the manufacturing industries in California. To address this concern, we further exclude California from our analysis sample and re-do our main analysis. Table A.6 summarizes the results. As can be seen below, the estimates are both qualitatively and quantitatively similar to those in Table 4. It indicates that our results are robust to drop California.

Table 14
Excluding Rust Belt states.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.116***	−0.043**	−0.043**	−0.058***
	(0.035)	(0.016)	(0.017)	(0.019)
After × NBP	0.316***	0.146**	0.146**	0.163***
	(0.084)	(0.058)	(0.061)	(0.057)
After × Manuf	−0.039	−0.027	−0.027	−0.012
	(0.033)	(0.016)	(0.017)	(0.018)
Observations	72,868	72,868	72,868	72,868
R-squared	0.96	0.98	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). In this sample, we exclude Rust Belt states, including Illinois, Indiana, Michigan, Ohio, and Pennsylvania. *After* × *NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table 15
Does exposure to Chinese import penetration matter?.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.125***	−0.044***	−0.044***	−0.046***
	(0.030)	(0.012)	(0.013)	(0.016)
After × NBP	0.299***	0.125**	0.126**	0.121**
	(0.095)	(0.058)	(0.061)	(0.059)
After × Manuf	−0.048*	−0.024*	−0.024	−0.014
	(0.026)	(0.014)	(0.014)	(0.014)
After × NBP × ImP	0.061	0.030	0.030	0.033
	(0.050)	(0.026)	(0.027)	(0.028)
After × ImP	−0.078*	−0.022	−0.022	−0.015
	(0.043)	(0.023)	(0.024)	(0.016)
Observations	92,481	92,481	92,481	92,481
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After* × *NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. *ImP* measures the exposure to Chinese import penetration in each county in 2000. This measurement is obtained from David et al. (2013). Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

After × *NBP* and local housing supply elasticity in 2000 to Equation (5). The measurements on local housing supply elasticity in 2000 are obtained from Saiz (2010).[25]

Table 16 reports the results. As can be seen in column (4), the coefficient on the three-way interaction with local housing supply elasticity is statistically insignificant. More importantly, the coefficients on the manufacturing intensity interaction remain stable compared to those in Table 4. The results indicate that our estimated positive effects of the NBP on housing prices do not reflect the occurrence of housing bubble during the 2000s.

Adjacent states. As NO_x can be transported downwind for a long distance—and thus the treatment status for states adjacent to NBP regions is not obvious—they are excluded from our main analysis. To examine whether our results are robust to this step, we include these states as the control group. In Table A.5, we present the estimates by assigning states adjacent to NBP regions to the control group. The magnitude of the coefficients become slightly smaller, compared to those in Table 4. Overall, the patterns of our main results are stable.

[25] Saiz (2010) computed the local housing supply elasticity only for the metro areas with population larger than 500,000. Due to the data limitation, our sample decreases from 92,841 to 63,245.

Table 16
Local housing supply elasticity.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.129***	−0.028	−0.028	−0.042*
	(0.045)	(0.018)	(0.018)	(0.023)
After × NBP	0.276**	0.103*	0.103*	0.124*
	(0.113)	(0.051)	(0.051)	(0.068)
After × Manuf	−0.004	−0.010	−0.010	−0.004
	(0.044)	(0.020)	(0.020)	(0.023)
After × NBP × Elasticity	0.017	−0.017	−0.017	−0.015
	(0.030)	(0.014)	(0.014)	(0.014)
After × Elasticity	−0.131***	−0.049**	−0.049**	−0.036**
	(0.032)	(0.020)	(0.020)	(0.016)
Observations	63,245	63,245	63,245	63,245
R-squared	0.97	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. *Elasticity* measures the local housing supply elasticity in each metro area in 2000. This measurement is obtained from Saiz (2010). Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

6. Conclusions

This paper exploits both the air pollution and the employment reductions induced by a major cap-and-trade market to provide new evidence on how housing markets are affected by environmental policies. Our difference-in-differences estimates indicate that the growth in house prices was dampened in high-manufacturing-intensity areas in participating states, whereas low-manufacturing-intensity regions experienced a housing boom. Specifically, we find that a 1% increase in manufacturing intensity in 1998 reduces the effect of the NBP on house prices by 0.05%. For perspective, house prices in an area with 50% manufacturing intensity in 1998 decreased by 5.7%, while house prices in an area with 5% manufacturing intensity in 1998 rose by 4.2%. These results indicate that there do exist two channels (health and labor-market channel) through which house prices were affected by the environmental regulation.

We also find that the cap-and-trade market affected both loan applications and rejection rates, which supports our hypothesis that the negative effect of the NBP on labor markets in high-manufacturing-intensity areas weakens local housing demand. Furthermore, the NBP increased the probability of loan default for individuals in high-manufacturing-intensity-areas.

Nowadays, cap-and-trade systems have been widely adopted to tackle environmental problems (e.g., the Acid Rain Program, the European Union's Emission Trading Scheme, the Northeast Regional Greenhouse Gas Initiative, and so forth). This paper shows that emission markets may trigger adverse consequences. Specifically, our findings provide the evidence of wealth redistribution as a result of the NBP. Given the ongoing academic and policy debates over energy sector regulations, a comprehensive understanding of the impacts of emission markets is essential.

A. Appendix

Table A.1
Correlations between county characteristics.

VARIABLES	Manufacturing employment (%)
Median age	−0.0966
Bachelor's degree or higher (%)	−0.2810
College degree (%)	−0.3319
High school diploma (%)	0.3351
Less than a high school diploma (%)	0.2227
White (%)	−0.0015
African American (%)	0.1669
Asian (%)	−0.0973
Other races (%)	−0.2295

Table A.2
Robustness test: Manufacturing intensity between 1998 and 2002.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.111***	−0.039***	−0.039***	−0.042***
	(0.027)	(0.011)	(0.012)	(0.015)
After × NBP	0.245***	0.109**	0.110*	0.106*
	(0.089)	(0.054)	(0.056)	(0.053)
After × Manuf	−0.047*	−0.022*	−0.022	−0.013
	(0.025)	(0.013)	(0.013)	(0.013)
Observations	92,481	92,481	92,481	92,481
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the average logged ratio between manufacturing employment and total labor force in each county between 1998 and 2002. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table A.3
Robustness test: Nonparametric estimates.

VARIABLES	(1)	(2)	(3)
	Logged Median Price Per Sqr Ft		
After × NBP × **1**(Manuf < =5%)	0.061*	0.062*	0.063
	(0.032)	(0.034)	(0.045)
After × NBP × **1**(5% < Manuf < =10%)	0.030	0.030	0.017
	(0.041)	(0.043)	(0.043)
After × NBP × **1**(10% < Manuf < =15%)	0.037	0.037	0.027
	(0.043)	(0.044)	(0.040)
After × NBP × **1**(15% < Manuf < =40%)	−0.018	−0.018	−0.029
	(0.040)	(0.042)	(0.043)
After × NBP × **1**(40% < Manuf < =45%)	−0.025	−0.025	−0.027
	(0.041)	(0.043)	(0.056)
After × NBP × **1**(45% < Manuf < =50%)	−0.032	−0.032	−0.048
	(0.033)	(0.035)	(0.047)
After × NBP × **1**(50% < Manuf)	−0.052*	−0.052*	−0.074*
	(0.029)	(0.031)	(0.037)
Observations	92,481	92,481	92,481
R-squared	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	Yes	No	No
Zip Code Linear Trend	No	Yes	Yes
Zip Code Quadratic Trend	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). Due to space limitations, two-way interactions between *After* and manufacturing intensity groups are omitted. Ordinary least squares estimates. Standard errors in parentheses, clustered by state.

Table A.4
NBP effect on NO_x emissions.

VARIABLES	(1)	(2)	(3)
	Logged NO_x emissions in summertime		
After × NBP × Manuf		−0.004	−0.002
		(0.039)	(0.040)
After × NBP	−0.138***	−0.127	−0.168
	(0.038)	(0.136)	(0.142)
After × Manuf		0.018	0.012
		(0.026)	(0.025)
Observations	6139	6139	6139
R-squared	0.97	0.97	0.98
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	Yes	Yes	Yes
County Linear Trend	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is total NO_x emissions in summertime in each county-year cell (in logarithm). Ordinary least squares estimates. Standard errors in parentheses, clustered by state.

Table A.5
Robustness test: Assigning adjacent states to the control group.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP	0.177	0.101*	0.101*	0.087
	(0.109)	(0.051)	(0.053)	(0.061)
After × NBP × Manuf	−0.084**	−0.039***	−0.039***	−0.036**
	(0.035)	(0.013)	(0.013)	(0.018)
After × Manuf	−0.101***	−0.037**	−0.037**	−0.033*
	(0.032)	(0.015)	(0.016)	(0.017)
Observations	116,048	116,048	116,048	116,048
R-squared	0.96	0.98	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. In this sample, states adjacent to NBP states are assigned to the control group. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Table A.6
Robustness test: Dropping California.

VARIABLES	(1)	(2)	(3)	(4)
	Logged Median Price Per Sqr Ft			
After × NBP × Manuf	−0.106***	−0.049***	−0.049***	−0.045***
	(0.027)	(0.013)	(0.014)	(0.016)
After × NBP	0.348***	0.185***	0.185***	0.160***
	(0.092)	(0.042)	(0.044)	(0.052)
After × Manuf	−0.070***	−0.017	−0.017	−0.014
	(0.021)	(0.016)	(0.017)	(0.015)
Observations	80,328	80,328	80,328	80,328
R-squared	0.96	0.99	0.99	0.99
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County Linear Trend	No	Yes	No	No
Zip Code Linear Trend	No	No	Yes	Yes
Zip Code Quadratic Trend	No	No	No	Yes

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. This table reports results for the same set of regression models found in Table 4 but excludes California from the data. Each observation represents a zip-code-year cell. The dependent variable is the median home value per square foot for all home types (in logarithm). *After × NBP* equals 1 for all zip codes belonging to NBP states in 2003 (or 2004) through 2008. *Manuf* is the logged ratio between manufacturing employment and total labor force in each county in 1998. Ordinary least squares estimates for all columns. Standard errors in parentheses, clustered by state.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jeem.2019.06.006.

References

Agarwal, S., Deng, Y., Luo, C., Qian, W., 2015. The hidden peril: the role of the condo loan market in the recent financial crisis. Rev. Finance 20 (2), 467–500.
An, X., Deng, Y., Gabriel, S.A., 2016. Default Option Exercise over the Financial Crisis and beyond. NUS IRES Working Paper 2016-003. .
Avery, R.B., Brevoort, K.P., Canner, G.B., 2007. The 2006 hmda data. Fed. Reserve Bull. 93, A73–A109.
Bayer, P., Keohane, N., Timmins, C., 2009. Migration and hedonic valuation: the case of air quality. J. Environ. Econ. Manag. 58 (1), 1–14.
Chay, K.Y., Greenstone, M., 2003. The impact of air pollution on infant mortality: evidence from geographic variation in pollution shocks induced by a recession. Q. J. Econ. 118 (3), 1121–1167.
Chay, K.Y., Greenstone, M., 2005. Does air quality matter? evidence from the housing market. J. Political Econ. 113 (2), 376–424.
Currie, J., Davis, L., Greenstone, M., Walker, R., 2015. Environmental health risks and housing values: evidence from 1,600 toxic plant openings and closings. Am. Econ. Rev. 105 (2), 678–709.
Currie, J., Neidell, M., 2005. Air pollution and infant health: what can we learn from California's recent experience? Q. J. Econ. 1003–1030.
Curtis, E.M., 2014. Who Loses under Power Plant Cap-And-Trade Programs? NBER Working Paper 20808. .
David, H., Dorn, D., Hanson, G.H., 2013. The China syndrome: local labor market effects of import competition in the United States. Am. Econ. Rev. 103 (6), 2121–2168.
Deschenes, O., Greenstone, M., Shapiro, J.S., 2012. Defensive Investments and the Demand for Air Quality: Evidence from the NOx Budget Program and Ozone Reductions. NBER Working Paper 18267. .
Fowlie, M., 2010. Emissions trading, electricity restructuring, and investment in pollution abatement. Am. Econ. Rev. 100 (3), 837–869.
Fowlie, M., Knittel, C.R., Wolfram, C., 2012. Sacred cars? optimal regulation of stationary and non-stationary pollution sources. Am. Econ. J. Econ. Policy 4 (1), 98–126.
Glaeser, E.L., Gyourko, J., 2005. Urban decline and durable housing. J. Political Econ. 113 (2), 345–375.
Greenstone, M., 2002. The impacts of environmental regulations on industrial activity: evidence from the 1970 and 1977 clean air act amendments and the census of manufactures. J. Political Econ. 110 (6), 1175–1219.
Greenstone, M., List, J.A., Syverson, C., 2012. The Effects of Environmental Regulation on the Competitiveness of Us Manufacturing. NBER Working Paper 18392. .
Guerrieri, V., Hartley, D., Hurst, E., 2013. Endogenous gentrification and housing price dynamics. J. Public Econ. 100, 45–60.
Howard, G., Deng, Y., Liebersohn, J., 2017. The Geography Channel of House Price Appreciation: Did the Decline in Manufacturing Partially Cause the Housing Boom. Unpublished Manuscript.
Hsiang, S.M., 2010. Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. Proc. Natl. Acad. Sci. 107 (35), 15367–15372.
Kahn, M.E., Mansur, E.T., 2013. Do local energy prices and regulation affect the geographic concentration of employment? J. Public Econ. 101, 105–114.
Kim, C.W., Phipps, T.T., Anselin, L., 2003. Measuring the benefits of air quality improvement: a spatial hedonic approach. J. Environ. Econ. Manag. 45 (1), 24–39.
Kline, P., 2010. Place based policies, heterogeneity, and agglomeration. Am. Econ. Rev. 100 (2), 383–387.
Linn, J., 2008. Technological modifications in the nitrogen oxides tradable permit program. Energy J. 153–176.
Linn, J., 2010. The effect of cap-and-trade programs on firms profits: evidence from the nitrogen oxides budget trading program. J. Environ. Econ. Manag. 59 (1), 1–14.
Luechinger, S., 2009. Valuing air quality using the life satisfaction approach. Econ. J. 119 (536), 482–515.
Mian, A., Sufi, A., 2009. The consequences of mortgage credit expansion: evidence from the us mortgage default crisis. Q. J. Econ. 124 (4), 1449–1496.
Polinsky, A.M., Shavell, S., 1976. Amenities and property values in a model of an urban area. J. Public Econ. 5 (12), 119–129.
Quigley, J.M., Raphael, S., 2005. Regulation and the high cost of housing in California. Am. Econ. Rev. 95 (2), 323–328.

Roback, J., 1982. Wages, rents, and the quality of life. J. Political Econ. 90 (6), 1257–1278.
Saiz, A., 2010. The geographic determinants of housing supply. Q. J. Econ. 125 (3), 1253–1296.
Schlenker, W., Walker, W.R., 2015. Airports, air pollution, and contemporaneous health. Rev. Econ. Stud. 83 (2), 768–809.
Shapiro, J.S., Walker, R., 2015. Why Is Pollution from Us Manufacturing Declining? the Roles of Trade, Regulation, Productivity, and Preferences. NBER Working Paper 20879. .
Streets, D., Chang, Y.-S., Tompkins, M., Ghim, Y., Carter, L., 2001. Efficient regional ozone control strategies for the eastern United States. J. Environ. Manag. 61 (4), 345–365.
USEPA, 2009. The Nox Budget Trading Program: 2008 Highlights. USEPA, Washington, DC.
Walker, W.R., 2011. Environmental regulation and labor reallocation: evidence from the clean air act. Am. Econ. Rev. 101 (3), 442–447.
Walker, W.R., 2013. The transitional costs of sectoral reallocation: evidence from the clean air act and the workforce. Q. J. Econ. 128 (4), 1787–1835.
Zheng, S., Kahn, M.E., Liu, H., 2010. Towards a system of open cities in China: home prices, fdi flows and air quality in 35 major cities. Reg. Sci. Urban Econ. 40 (1), 1–10.