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-experiment—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.

Keywords: NO_x Budget Trading Program, Air pollution, House prices, Manufacturing intensity

JEL classification: I10, J60, L60, O18, Q52, Q53, Q58, R21, R23

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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.

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

[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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nitrogen oxides (NO_x) emissions.[3] It was implemented from 2003 to 2008 in nineteen states in addition to Washington, D.C. (see Figure 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 Figure 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

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

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. Figure 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, house prices in areas without manufacturing employment in 1998 rose by 12.69% as a result of air quality improvement. This finding is consistent with the hedonic theory. More importantly, we find that a 1% increase in manufacturing intensity in 1998 statistically significantly reduced the increase in house prices by 0.043%. For perspective, house prices in an area in which manufacturing intensity in 1998 was 50% decreased by 4.22%. In contrast, house prices in an area in which manufacturing intensity in 1998 was 5% shifted up by 4.99%. These estimates imply that the negative impacts of the NBP on labor markets further dampened the growth

[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.

house prices in high-manufacturing-intensity regions.

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 4.45% and 2.22%, 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 1.14 and 0.84 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 use an alternative measure of manufacturing intensity in regressions, which accounts for energy-intensity levels for different manufacturing industries. Third, 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. 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 important contributions to the literature. First, 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. Second, this study provides strong evidence that environmental policy could also negatively impact housing markets due to its adverse effects on labor markets, i.e., the labor-market channel. This harmful effect on housing markets has not been documented in previous studies. As a result of the emission market, house prices in NBP areas with low and high manufacturing intensity increased and decreased, respectively. People who owned houses in low-manufacturing-intensity areas enjoyed an increase in their wealth, but their counterfactuals in high-manufacturing-intensity regions suffered a loss.

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 operated 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), 2,500 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.

Deschenes et al. (2012) found that the NBP dramatically reduced the NO_x emissions by around 34-38%. Correspondingly, ozone pollution concentrations in NBP states decreased by about 7%. The pharmaceutical expenditures and mortality rates declined as a result of the air quality improvement. Based on their estimates, the health benefits from

[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.

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

the NBP were substantial. Hedonic theory predicts that house prices will increase as air quality improves, with other factors constant (Chay and Greenstone 2005). Considering Rosen's model specifically (Rosen 1974), house prices can be denoted as a function of the houses' characteristics, e.g., the number of units, year of built, air quality, and so forth:

$$H = H(a_1, a_2, ..., a_n). \tag{1}$$

By taking the partial derivative of $H(\cdot)$ with regard to the air quality where houses are located, we can derive the marginal implicit price of air quality. As the air quality in eastern states is improved by the NBP, house prices in these regions are expected to rise, holding other factors constant.

In addition to health effects, the NBP also 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. 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 as shown in Figure 4.[9] We depict the age distribution of home buyers (first-time and repeat buyers) in Figure 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.

To summarize, qualitative analyses suggest that the environmental regulation affected the house prices through two channels. First, the air quality improvement decreased the pharmaceutical expenditures and mortality rates. Therefore, people have been willing to pay a higher price to live there. The role of this health channel on house prices has been

[9] Figure 4 is obtained from Curtis (2014) and displays event-time coefficient estimates for five age groups based on Equation (3) used in his study.

extensively discussed in the literature. On the other hand, the NBP had negative impacts on the manufacturing employment outcomes, which may trigger a decline in housing markets. This labor-market channel has been ignored by the literature. We hypothesize that the labor-market channel dominates in high-manufacturing-intensity regions, while health channel is critical in low-manufacturing-intensity regions. The main target of this paper is to identify which housing markets were affected and how.

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.[10] 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

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

Home Value Index (ZHVI) and the FCSW index reaches 0.91.[11] 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 fol-

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

lowing origination.

As the BBX does not contain borrower characteristics, we match the BBX data with the HMDA data using a step-by-step criteria.[12] 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.[13] 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 es-

[12]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).

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

tablishments, 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.[14]

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

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

in Michigan since only a few counties joined the NBP. Sample statistics are summarized in Tables 1 and 2.

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 Figure 5 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 Figure 5 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.

Figure 6 provides another set of comparisons. In Panel (a), we contrast the same relationship as in Figure 5 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 Figure 6 yields a similar implication as in Figure 5, 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 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.[15] These two concerns further motivate our empirical analyses.

[15]Details are discussed in the results section.

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:

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

where the dependent variable is the median home value per square foot 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 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. Vectors of the zip-code-specific linear time trend, $\mu_i * t$, 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.

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:

$$Y_{it} = \beta(After_t \times NBP_i \times Manuf_c) + \gamma(After_t \times NBP_i) + \delta(After_t \times Manuf_c) + \mu_i + \lambda_t + \mu_i * t + \varepsilon_{it}. \quad (3)$$

where $Manuf_c$ denotes the logged ratio between manufacturing employment and total labor force in county c in 1998.[16] 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. 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 statistically significantly negative. Additionally, the coefficient γ measures the effect of the NBP on house prices in areas with no manufacturing employment in 1998, i.e., $Manuf_c = 0$. These districts are assumed to enjoy an improvement in air quality, and their economic activities should be affected less, i.e., health channel on house prices dominates. We predict that the sign of γ should be positive.

[16]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.3, 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.

4.1 Identification assumption

The validity of this difference-in-differences estimator requires that house prices in the NBP and non-NBP regions share a parallel trend before the market's initiation. Figure 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:

$$Y_{it} = \sum_{t=1998}^{2008} \zeta_t (NBP_i \times Manuf_c) + \gamma(After_t \times NBP_i) + \delta(After_t \times Manuf_c)$$

$$\mu_i + \lambda_t + \varepsilon_{it}. \quad (4)$$

In practice, 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. 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.

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, Figure 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 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. To sum up, both Figure 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 (3). 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 $After \times NBP$ 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 $After \times NBP \times Manuf$ 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 further 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. Estimates in column (3) imply that house prices in NBP areas with no manufacturing employment in 1998 increased by 12.69%, which is a sizeable positive effect. More importantly, the coefficient on the three-way interaction indicates that a 1% increase in manufacturing intensity in 1998 reduced the increase in house prices by 0.043%.

Next, we use examples to interpret the estimates in column (3). The NBP decreased the house prices in places with 50%, 40%, and 30% manufacturing intensity in 1998 by 4.22%, 3.28%, and 2.08%, respectively.[17] On the other hand, the house prices in districts with 10% and 5% manufacturing intensity in 1998 rose by 2.38% and 4.99%, respectively. These calculations assume a specific functional form of the effect of manufacturing intensity. To relax the functional form assumption, Table A.4 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 6.13%, 3.01%, 3.73%, -1.78%, -2.46%, -3.16%, and -5.18%, respectively. In column (2), we find that the monotonic pattern is robust, by adding the zip-code-specific linear trends.

Identification assumption test. We adopt an event-study framework to examine the presence of trends in advance of the market's operation. Using Equation (4), we can estimate the NBP effect on house prices in each year. The estimates are plotted in Figure 7. 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, Figure 7 illustrates the NBP effect

[17]The figures are computed as follows: $4.22\% = (0.1269 + -0.043 \times log(50+1)) \times 100\%$; $3.28\% = (0.1269 + -0.043 \times log(40+1)) \times 100\%$; $2.08\% = (0.1269 + -0.043 \times log(30+1)) \times 100\%$.

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). As shown in Figure 4, the magnitude of NBP effects on labor markets gradually became larger after 2003, and slightly decreased after 2006. These consistent patterns support our contention that the negative effects on housing markets come from the NBP effects on labor markets.

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 (3) to estimate the impacts. As shown in column (1) in Table 5, applications in NBP areas with no manufacturing employment in 1998 increased by 35.96%, a sizeable positive effect. Additionally, the coefficient on the three-way interaction indicates that a 1% increase in manufacturing intensity in 1998 reduced the application volume increase by 0.1028%. 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 4.45% and 2.22%, respectively. For districts with 10% and 5% manufacturing intensity in 1998, their application amount shifted up by 11.31% and 17.54%, respectively.

Column (2) in Table 5 indicates that the rejection rate for loan applications in NBP areas with no manufacturing employment in 1998 decreased by 4.21 percentage points (the average rejection rate is 22.06%). The three-way interaction is positive and statistically significant at the 1% level. The NBP increased the rejection rates in areas with 50%, 40%, and 30% manufacturing intensity in 1998 by 1.14, 0.84, and 0.46 percentage points, respectively. Meanwhile, the house prices in districts with 10% and 5% manufacturing intensity in 1998 decreased by 0.95 and 1.77 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 following origination. The results in Table 5 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 (2) in Table 6 presents the estimates using Equation (3). In column (3), 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 loan default risk by 0.0208.

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.5 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 17.34%. Estimates in column (2) suggest that the NBP effect on NO_x emissions do not vary by areas with different manufacturing intensities. 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 7 examine whether the proportion of agricultural, service, and other industry employment in 1998 plays an important role in determining house prices.[18] 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 $After \times NBP$ and other county characteristics. Notably, as shown in Table 8, the coefficient on $After \times NBP \times Manuf$ remains stable, while most coefficients on other three-way interactions are not statistically significantly different from zero.[19] We use the Wald test to check whether the summation of all other interactions is equal to zero. The p-values in columns (1) and (2)

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

[19]The coefficient on $After \times NBP$ is no longer comparable to that in column (3) in Table 4. The coefficient in Table 8 represents the NBP effect on house prices for areas with all characteristics equal to zero.

are 0.33 and 0.36, 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 9 reports the corresponding estimates. The statistically insignificant two-way interaction term, shown in column (2), indicates that the supply curve in NBP areas with no manufacturing employment in 1998 was not affected. Additionally, the three-way interactions are not statistically significantly different from zero.

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-hour 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 $After \times NBP$ and non-attainment status in 2004 to Equation (3).

Table 10 statistically summarizes estimates based on the new specification. Coefficients on the three-way interaction with non-attainment status are negative and statistically significant at the 10% level. More importantly, the coefficients on the manufacturing intensity interaction are affected less than those in Table 4. The comparison demonstrates that including these controls in the regressions does not have a significant influence on our main results.

Energy intensity. 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, 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.[20] 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 11. They demonstrate that our main conclusions do not change much. Specifically, as shown in column (3), house prices

[20]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.

in districts with no manufacturing employment in 1998 increased by 13.25%, similar to that in Table 4. In addition, the three-way interaction demonstrates that a 1% rise in manufacturing intensity in 1998 reduced the increase in house prices by 0.036%, which is also comparable to that in Table 4.

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 trends, which may partly address this concern. To further reduce heterogeneity, we exclude these Rust Belt states from our regression sample. Table 12 presents estimates based on the new sample. In column (3), the three-way interaction indicates that a 1% rise in manufacturing intensity in 1998 reduced the increase in house prices by 0.043%, 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.

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.2, 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.

House types. In Panel A in Table 13, we replace the dependent variable with ZHVI for all home types. Since the NBP is assumed to have no influence on home size, we expect that the NBP impact on ZHVI should be similar to that on median price per square foot. Columns (1)-(3) replicate the specifications in Table 4. Column (3) indicates that house prices in areas with no manufacturing employment in 1998 increased by 12.62%. The three-way interaction shows that a 1% rise in manufacturing intensity in 1998 reduced the increase in house prices by 0.043%. Magnitudes of the effects are similar to those in Table 4.

Next, we examine the NBP effects on single-family houses and on condominiums and co-ops, respectively. Both Panels B and C demonstrate that the air pollution abatement resulted in a rise in house prices in low-manufacturing-intensity areas. However, the growth in house prices was dampened in high-manufacturing-intensity NBP areas. These results suggest that our main results are not driven by a particular type of housing.

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 increase in house prices by 0.043%. For perspective, house prices in an area with 50% manufacturing intensity in 1998 decreased by 4.22%, while house prices in an area with 5% manufacturing intensity in 1998 rose by 4.99%. 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.

From an efficiency view, cap-and-trade systems have advantages compared to command-and-control-style regulations. Therefore, they are being 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. It comes to show through this paper that although emission markets provide a market-based solution to abate air pollution, they may also generate harmful side effects. In particular, our findings present the first evidence of wealth redistribution as a result of environmental regulations. Given the ongoing academic and policy debates over energy sector regulations, a comprehensive understanding of the impacts of emission markets is essential.

References

Agarwal, S., Deng, Y., Luo, C., and Qian, W. (2015). The hidden peril: The role of the condo loan market in the recent financial crisis. *Review of Finance*, 20(2):467–500.

An, X., Deng, Y., and 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., and Canner, G. B. (2007). The 2006 hmda data. *Federal Reserve Bulletin*, 93:A73–A109.

Bayer, P., Keohane, N., and Timmins, C. (2009). Migration and hedonic valuation: The case of air quality. *Journal of Environmental Economics and Management*, 58(1):1–14.

Chay, K. Y. and Greenstone, M. (2003). The impact of air pollution on infant mortality: Evidence from geographic variation in pollution shocks induced by a recession. *The Quarterly Journal of Economics*, 118(3):1121–1167.

Chay, K. Y. and Greenstone, M. (2005). Does air quality matter? evidence from the housing market. *Journal of Political Economy*, 113(2):376–424.

Currie, J., Davis, L., Greenstone, M., and Walker, R. (2015). Environmental health risks and housing values: Evidence from 1,600 toxic plant openings and closings. *The American Economic Review*, 105(2):678–709.

Currie, J. and Neidell, M. (2005). Air pollution and infant health: What can we learn from california's recent experience? *The Quarterly Journal of Economics*, pages 1003–1030.

Curtis, E. M. (2014). Who loses under power plant cap-and-trade programs? *NBER Working Paper 20808*.

Deschenes, O., Greenstone, M., and 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. *The American Economic Review*, 100(3):837–869.

Fowlie, M., Knittel, C. R., and Wolfram, C. (2012). Sacred cars? optimal regulation of stationary and non-stationary pollution sources. *American Economic Journal: Economic Policy*, 4(1):98–126.

Glaeser, E. L. and Gyourko, J. (2005). Urban decline and durable housing. *Journal of Political Economy*, 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. *Journal of Political Economy*, 110(6):1175–1219.

Greenstone, M., List, J. A., and Syverson, C. (2012). The effects of environmental regulation on the competitiveness of us manufacturing. *NBER Working Paper 18392*.

Guerrieri, V., Hartley, D., and Hurst, E. (2013). Endogenous gentrification and housing price dynamics. *Journal of Public Economics*, 100:45–60.

Kahn, M. E. and Mansur, E. T. (2013). Do local energy prices and regulation affect the geographic concentration of employment? *Journal of Public Economics*, 101:105–114.

Kim, C. W., Phipps, T. T., and Anselin, L. (2003). Measuring the benefits of air quality improvement: A spatial hedonic approach. *Journal of Environmental Economics and Management*, 45(1):24–39.

Linn, J. (2008). Technological modifications in the nitrogen oxides tradable permit program. *The Energy Journal*, pages 153–176.

Linn, J. (2010). The effect of cap-and-trade programs on firms profits: Evidence from the nitrogen oxides budget trading program. *Journal of Environmental Economics and Management*, 59(1):1–14.

Luechinger, S. (2009). Valuing air quality using the life satisfaction approach. *The Economic Journal*, 119(536):482–515.

Mian, A. and Sufi, A. (2009). The consequences of mortgage credit expansion: Evidence from the us mortgage default crisis. *The Quarterly Journal of Economics*, 124(4):1449–1496.

Quigley, J. M. and Raphael, S. (2005). Regulation and the high cost of housing in california. *The American Economic Review*, 95(2):323–328.

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1):34–55.

Schlenker, W. and Walker, W. R. (2015). Airports, air pollution, and contemporaneous health. *The Review of Economic Studies*, 83(2):768–809.

Shapiro, J. S. and 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., and Carter, L. (2001). Efficient regional ozone control strategies for the eastern united states. *Journal of Environmental Management*, 61(4):345–365.

USEPA (2009). The nox budget trading program: 2008 highlights. *Washington, DC: USEPA*.

Walker, W. R. (2011). Environmental regulation and labor reallocation: Evidence from the clean air act. *The American Economic Review*, 101(3):442–447.

Walker, W. R. (2013). The transitional costs of sectoral reallocation: Evidence from the clean air act and the workforce. *The Quarterly Journal of Economics*, 128(4):1787–1835.

Zheng, S., Kahn, M. E., and Liu, H. (2010). Towards a system of open cities in china:

Home prices, fdi flows and air quality in 35 major cities. *Regional Science and Urban Economics*, 40(1):1–10.

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 (1,000$)	92,481	0.13	0.10	0.02	1.12
Home Value Index (1,000$)	90,281	219.47	186.74	24.15	3,809.13
Single-family HVI (1,000$)	89,810	230.78	209.68	24.15	3,840.52
Condo HVI (1,000$)	36,321	191.13	127.74	27.73	1,718.07
Housing supply (county-year level)					
Residential building permits	22,626	904.12	3,006.44	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 8,275 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.

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.

Table 3: Overall impact of the NBP on house prices

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	-0.0609	0.0043	0.0043
	(0.0852)	(0.0386)	(0.0403)
Observations	92,481	92,481	92,481
R-squared	0.9588	0.9857	0.9878
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). $After \times NBP$ 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.

Table 4: Impact by areas with different manufacturing intensities

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	0.2913***	0.1262**	0.1269**
	(0.0959)	(0.0590)	(0.0617)
After× NBP× Manuf	-0.1216***	-0.0428***	-0.0430***
	(0.0290)	(0.0125)	(0.0131)
After× Manuf	-0.0519**	-0.0246*	-0.0246
	(0.0255)	(0.0140)	(0.0146)
Observations	92,481	92,481	92,481
R-squared	0.9631	0.9858	0.9879
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). $After \times NBP$ 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 5: Impact on loan application volume and rejection rate

VARIABLES	(1) Logged Mortgage Application Volume	(2) Rejection Rate (%)
After× NBP	0.3596*	-4.2071***
	(0.2024)	(1.5405)
After× NBP× Manuf	-0.1028*	1.3588***
	(0.0571)	(0.4209)
After× Manuf	-0.0613	-0.3987
	(0.0605)	(0.2596)
Observations	581,971	581,971
R-squared	0.2350	0.3036
County FE	Yes	Yes
Year FE	Yes	Yes
County Linear Trend	Yes	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. $After \times NBP$ 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.

Table 6: Impact on loan performance

	(1)	(2)	(3)
VARIABLES		Default Dummy	
After× NBP	-0.0328	-0.0320	-0.0315
	(0.0375)	(0.0237)	(0.0238)
After× NBP× Manuf	0.0266**	0.0210***	0.0208***
	(0.0110)	(0.0075)	(0.0075)
After× Manuf	-0.0044	0.0025	0.0008
	(0.0135)	(0.0062)	(0.0059)
Male			-0.0123***
			(0.0020)
White			-0.0266***
			(0.0086)
African American			0.0418***
			(0.0058)
Asian			-0.0269***
			(0.0093)
Single-family			0.0179***
			(0.0058)
PUD			-0.0024
			(0.0034)
Observations	430,227	430,227	430,227
R-squared	0.0732	0.0781	0.0838
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	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. $After \times NBP$ 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.

Table 7: Do nonmanufacturing industries matter?

	(1)	(2)	(3)	(4)
VARIABLES		Logged Median Price Per Sqr Ft		
After× NBP	-0.0030	-0.2576*	-0.2301*	
	(0.0385)	(0.1513)	(0.1147)	
After× NBP× Manuf				-0.0437***
				(0.0155)
After× Manuf				0.0143
				(0.0398)
After× NBP× Agriculture	-0.0232			-0.0014
	(0.0390)			(0.0352)
After× Agriculture	0.0181			0.0354
	(0.0299)			(0.0340)
After× NBP× Service		0.0635		-0.0132
		(0.0394)		(0.0176)
After× Service		0.0808**		0.1166
		(0.0315)		(0.1059)
After× NBP× Others			0.0665*	0.0509*
			(0.0367)	(0.0261)
After× Others			-0.0329	-0.0099
			(0.0258)	(0.0531)
Observations	92,481	92,481	92,481	92,481
R-squared	0.9940	0.9940	0.9940	0.9941
Zip Code FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Zip Code Linear 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). $After \times NBP$ 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.

Table 8: Do other population characteristics matter?

VARIABLES	(1) Logged Median Price Per Sqr Ft	(2)
After× NBP× Manuf	-0.0410***	-0.0413***
	(0.0131)	(0.0137)
After× NBP× Median Age	0.1811	0.1810
	(0.1422)	(0.1485)
After× NBP× Bachelor and above	0.0218	0.0214
	(0.0560)	(0.0587)
After× NBP× College	0.1011	0.1015
	(0.1155)	(0.1208)
After× NBP× High School	-0.0518	-0.0520
	(0.0834)	(0.0872)
After× NBP× Less than High School	-0.0011	-0.0011
	(0.0030)	(0.0031)
After× NBP× White	-0.1117	-0.1117
	(0.0853)	(0.0892)
After× NBP× African American	-0.0413**	-0.0412**
	(0.0156)	(0.0164)
After× NBP× Asian	-0.0188	-0.0188
	(0.0130)	(0.0136)
Observations	92,481	92,481
R-squared	0.9865	0.9886
Zip Code FE	Yes	Yes
Year FE	Yes	Yes
County Linear Trend	Yes	No
Zip Code Linear Trend	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). $After \times NBP$ 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 9: NBP impact on residential building permits

	(1)	(2)
VARIABLES	Logged Residential Building Permits	
After× NBP	-0.2842**	0.1108
	(0.1351)	(0.1002)
After× NBP× Manuf	0.0448	-0.0383
	(0.0454)	(0.0307)
After× Manuf	-0.0449	0.0395
	(0.0397)	(0.0324)
Observations	22,746	22,746
R-squared	0.9406	0.9612
County FE	Yes	Yes
Year FE	Yes	Yes
County Linear Trend	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. $After \times NBP$ 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.

Table 10: NAAQS regulations

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	0.3148***	0.1349***	0.1360***
	(0.0949)	(0.0458)	(0.0480)
After× NBP× Manuf	-0.1184***	-0.0447***	-0.0450***
	(0.0277)	(0.0114)	(0.0120)
After× Manuf	-0.0370*	-0.0097	-0.0096
	(0.0191)	(0.0086)	(0.0090)
After× NBP× Non-att	-0.1187*	-0.0417*	-0.0420*
	(0.0685)	(0.0233)	(0.0242)
After× Non-att	0.2056***	0.1206***	0.1205***
	(0.0681)	(0.0305)	(0.0318)
Observations	92,481	92,481	92,481
R-squared	0.9671	0.9863	0.9884
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). $After \times NBP$ 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 11: An alternative measurement of manufacturing intensity

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	0.2887***	0.1318***	0.1325***
	(0.0960)	(0.0262)	(0.0273)
After× NBP× Manuf Energy	-0.0986***	-0.0361***	-0.0363***
	(0.0320)	(0.0102)	(0.0106)
After× Manuf	0.0505*	0.0240*	0.0240*
	(0.0266)	(0.0136)	(0.0141)
Observations	92,481	92,481	92,481
R-squared	0.9606	0.9858	0.9879
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). $After \times NBP$ 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.

Table 12: Excluding Rust Belt states

VARIABLES	(1)	(2) Logged Median Price Per Sqr Ft	(3)
After× NBP	0.3157***	0.1456**	0.1465**
	(0.0844)	(0.0580)	(0.0607)
After× NBP× Manuf	-0.1161***	-0.0431**	-0.0434**
	(0.0349)	(0.0165)	(0.0172)
After× Manuf	-0.0388	-0.0272	-0.0271
	(0.0326)	(0.0164)	(0.0171)
Observations	72,868	72,868	72,868
R-squared	0.9632	0.9846	0.9867
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). In this sample, we exclude Rust Belt states, including Illinois, Indiana, Michigan, Ohio, and Pennsylvania. $After \times NBP$ 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 13: Impacts by home type

	(1)	(2)	(3)
VARIABLES		**A. All Home Types**	
After× NBP	0.2744***	0.1259**	0.1262**
	(0.0962)	(0.0593)	(0.0621)
After× NBP× Manuf	-0.1170***	-0.0428***	-0.0429***
	(0.0291)	(0.0128)	(0.0134)
After× Manuf	-0.0519**	-0.0241*	-0.0241
	(0.0250)	(0.0137)	(0.0144)
Observations	90,281	90,281	90,281
R-squared	0.9697	0.9882	0.9900
VARIABLES		**B. Single-family Houses**	
After× NBP	0.2590**	0.1202*	0.1206*
	(0.0993)	(0.0606)	(0.0634)
After× NBP× Manuf	-0.1114***	-0.0406***	-0.0407***
	(0.0292)	(0.0130)	(0.0136)
After× Manuf	-0.0550**	-0.0249*	-0.0248
	(0.0240)	(0.0143)	(0.0149)
Observations	89,810	89,810	89,810
R-squared	0.9723	0.9893	0.9908
VARIABLES		**C. Condos and Co-ops**	
After× NBP	0.4233***	0.1630***	0.1634***
	(0.1129)	(0.0440)	(0.0459)
After× NBP× Manuf	-0.1728***	-0.0552***	-0.0553***
	(0.0570)	(0.0181)	(0.0188)
After× Manuf	0.0070	-0.0091	-0.0092
	(0.0586)	(0.0252)	(0.0262)
Observations	36,321	36,321	36,321
R-squared	0.9522	0.9797	0.9837
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear Trend	No	No	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1. Each observation represents a zip-code-year cell. The dependent variables for Panel A, B, and C are the logged Zillow HVI for all home types, single-family HVI, and condo and co-op HVI, respectively. $After \times NBP$ 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.

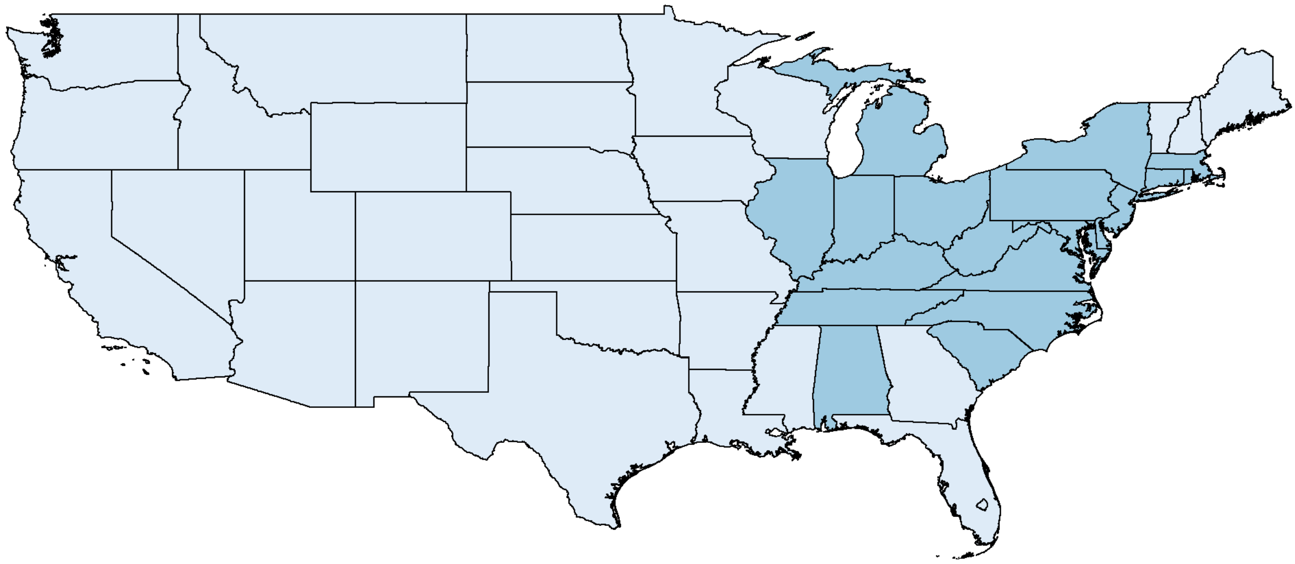
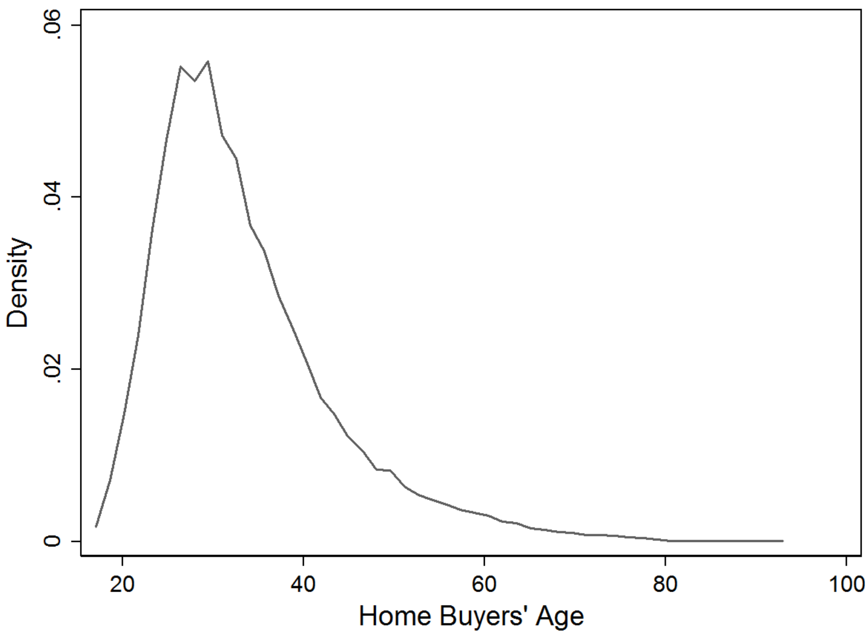
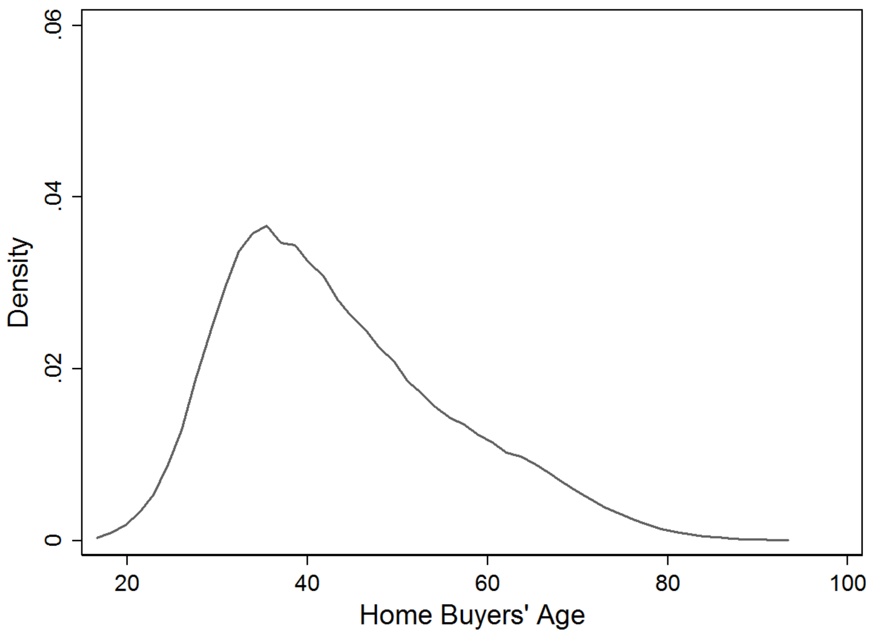


Figure 1: States covered in the analysis sample

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.



(a) First-time Buyers



(b) Repeat Buyers

Figure 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.

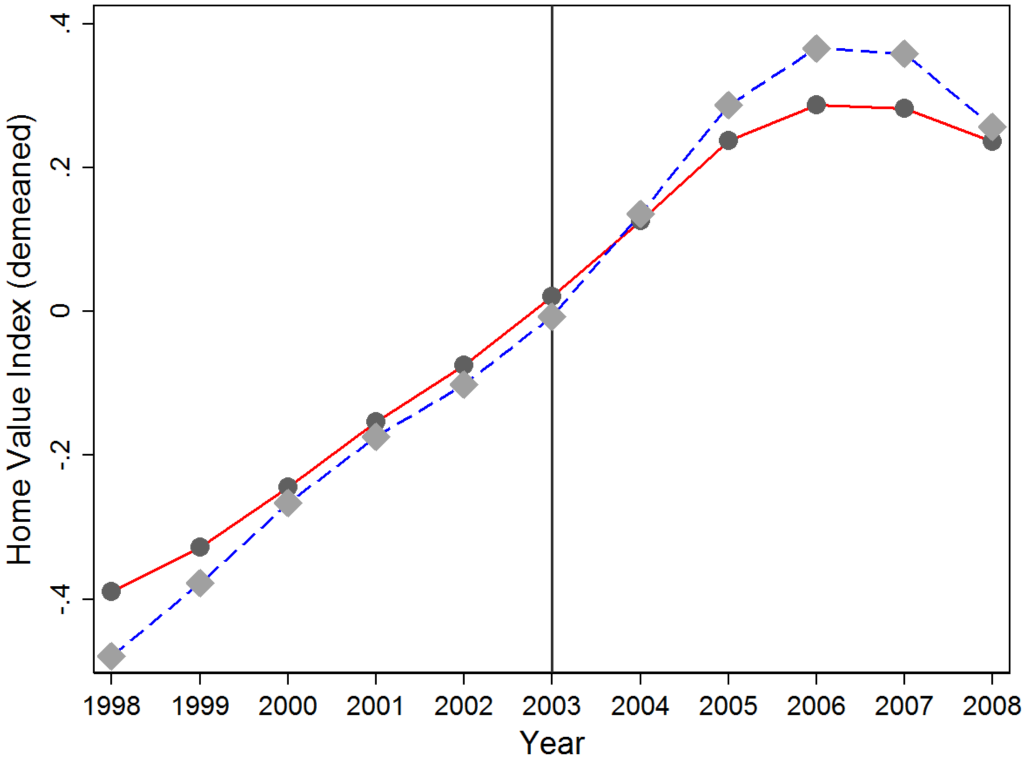


Figure 3: Average annual house prices in NBP and non-NBP states during the sample period.

Note: The solid red line denotes the average median home value per square foot (demeaned) in NBP regions in each year. The dashed blue line represents the average median home value per square foot (demeaned) in non-NBP regions in each year.

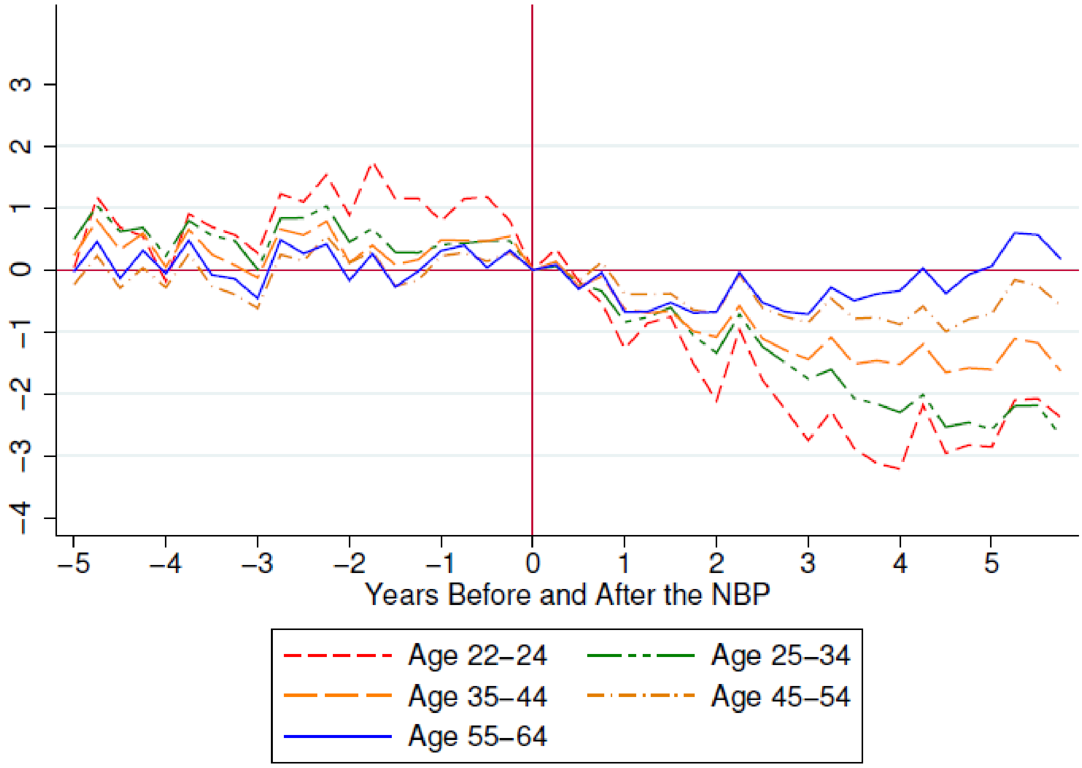
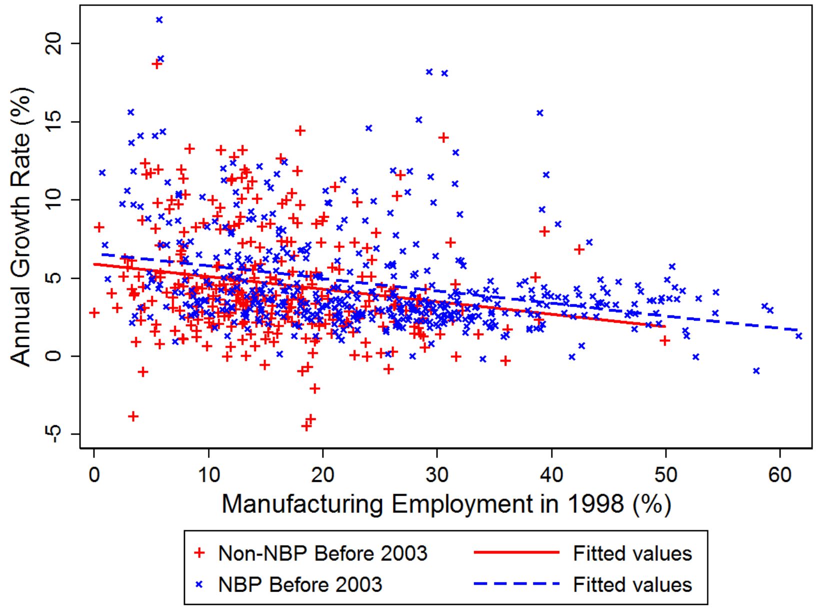
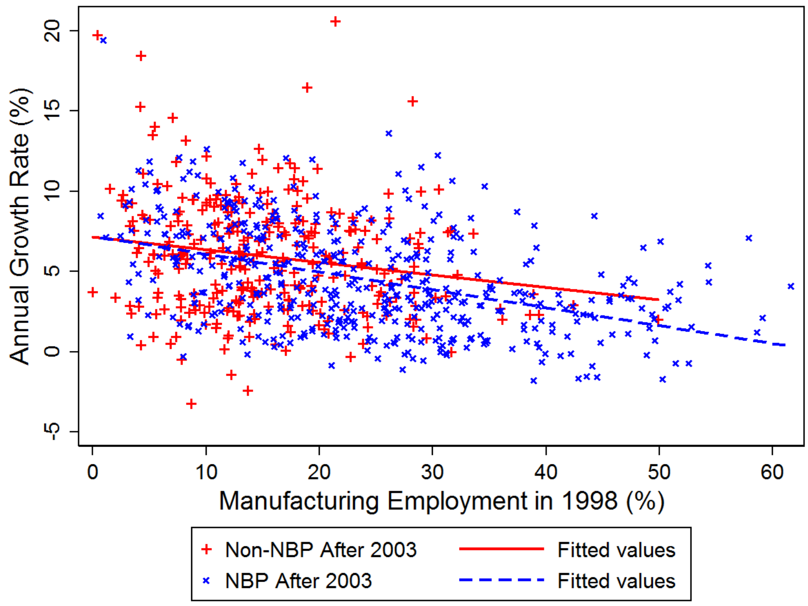


Figure 4: Impact of the NBP on employment by age group

Note: This figure is obtained from Curtis (2014). The plots are based on Equation (3) used in the study. The y-axis denotes the percentage change in employment.



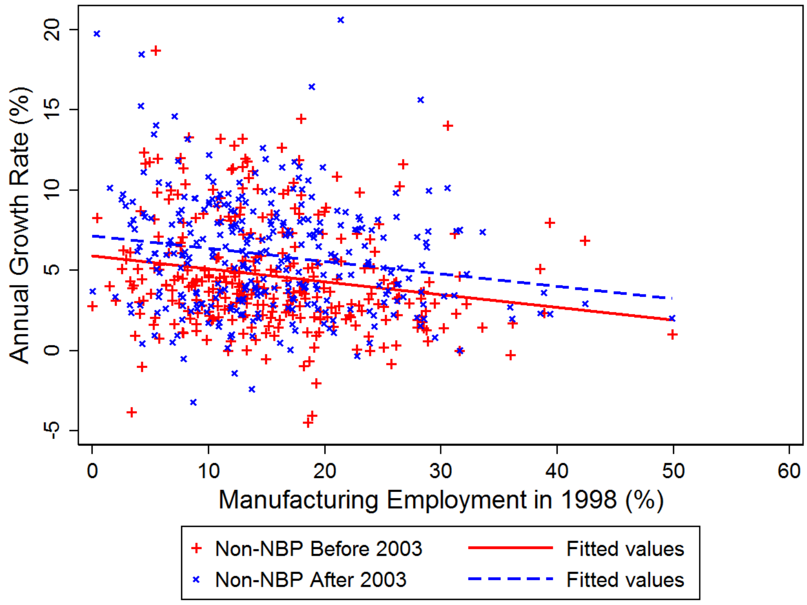
(a) NBP vs. Non-NBP before 2003



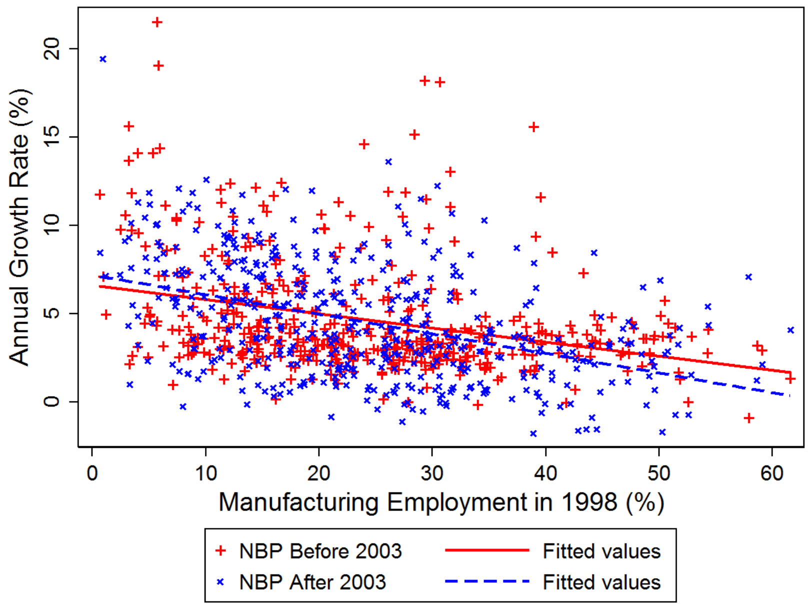
(b) NBP vs. Non-NBP after 2003

Figure 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 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.



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



(b) Before 2003 vs. after 2003 for NBP

Figure 6: 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.

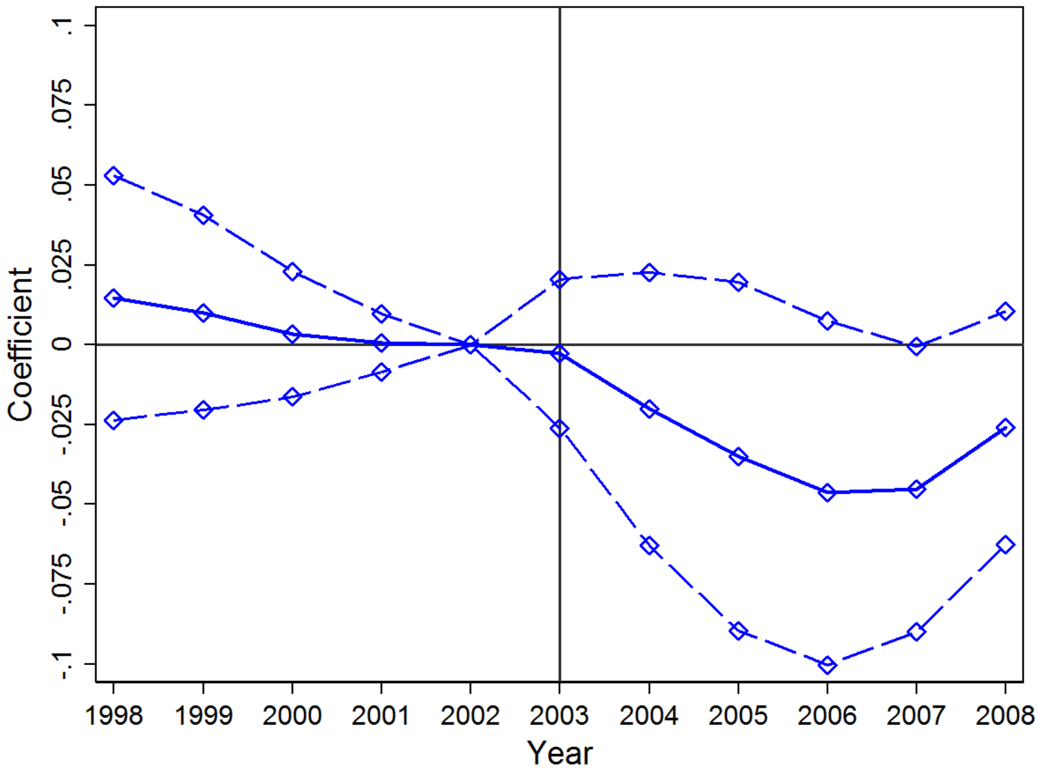


Figure 7: NBP effect across years

Note: Solid lines denote estimated coefficients. Dashed lines represent upper and lower bounds for the 95% confidence interval.

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: Assigning adjacent states to the control group

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	0.1769	0.1006*	0.1010*
	(0.1093)	(0.0512)	(0.0535)
After× NBP× Manuf	-0.0845**	-0.0386***	-0.0386***
	(0.0347)	(0.0129)	(0.0134)
After× Manuf	-0.1007***	-0.0370**	-0.0370**
	(0.0319)	(0.0152)	(0.0159)
Observations	116,048	116,048	116,048
R-squared	0.9601	0.9846	0.9868
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear Trend	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). $After \times NBP$ 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.3: Robustness test: Manufacturing intensity between 1998 and 2002

	(1)	(2)	(3)
VARIABLES		Logged Median Price Per Sqr Ft	
After× NBP	0.2450***	0.1091**	0.1097*
	(0.0893)	(0.0536)	(0.0561)
After× NBP× Manuf	-0.1113***	-0.0388***	-0.0390***
	(0.0273)	(0.0112)	(0.0118)
After× Manuf	-0.0467*	-0.0216*	-0.0216
	(0.0246)	(0.0127)	(0.0133)
Observations	92,481	92,481	92,481
R-squared	0.9633	0.9858	0.9880
Zip Code FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County Linear Trend	No	Yes	No
Zip Code Linear 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). $After \times NBP$ 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.4: Robustness test: Nonparametric estimates

	(1)	(2)
VARIABLES	Logged Median Price Per Sqr Ft	
After× NBP× **1**(Manuf<=5%)	0.0613*	0.0619*
	(0.0321)	(0.0336)
After× NBP× **1**(5%<Manuf<=10%)	0.0301	0.0302
	(0.0411)	(0.0429)
After× NBP× **1**(10%<Manuf<=15%)	0.0373	0.0373
	(0.0425)	(0.0445)
After× NBP× **1**(15%<Manuf<=40%)	-0.0178	-0.0178
	(0.0403)	(0.0421)
After× NBP× **1**(40%<Manuf<=45%)	-0.0246	-0.0248
	(0.0407)	(0.0425)
After× NBP× **1**(45%<Manuf<=50%)	-0.0316	-0.0319
	(0.0333)	(0.0349)
After× NBP× **1**(50%<Manuf)	-0.0518*	-0.0518*
	(0.0293)	(0.0306)
Observations	92,481	92,481
R-squared	0.9858	0.9879
Zip Code FE	Yes	Yes
Year FE	Yes	Yes
County Linear Trend	Yes	No
Zip Code Linear Trend	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.5: NBP effect on NO_x emissions

	(1)	(2)
VARIABLES	Logged NO_x emissions in summertime	
After× NBP	-0.138***	-0.127
	(0.038)	(0.136)
After× NBP× Manuf		-0.004
		(0.039)
After× Manuf		0.018
		(0.026)
Observations	6,139	6,139
R-squared	0.974	0.974
County FE	Yes	Yes
Year FE	Yes	Yes
County Linear Trend	Yes	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.