The impact of Noxious and Carcinogenic Pollutants in Adams County Colorado

A Hedonic and Repeat Sale Analysis

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Abstract

This paper will explore how carcinogenic and noxious pollutants emitted from Toxic Release Sites (TRI) effect housing prices in an urban area of Colorado. This is possible in an empirical model that considers the influence of commercial and industrial properties. My approach addresses an important source of omitted variable bias like issues of sorting, and agglomeration by disaggregating pollutant types and sites. I will also compare estimates using a hedonic and repeat sales model. Since I am using the repeat sales model, this can control for bias due to sorting. Results indicate that pollutant coefficients in the repeat sales model are higher than the hedonic coefficients. Overall, the effect of an additional TRI Sites on housing prices within a 1.5 km radius is a 6.3% decrease, an additional noxious pollutant has a 9% decrease, an additional carcinogenic pollutant contributes a 5% decrease, an additional industrial site has a 3% decrease on housing prices.

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1 Introduction

Previous literature suggests that pollution has impacts on property values, however there is room to explore how different locations respond to certain types of pollution. Even more so, differences in site selection, function, and pollutant intensity are all factors that can add more insight to this relationship. To understand the relationship between pollutants and land uses on property values a repeat sales framework and a hedonic analysis will be leveraged to understand how pollution interacts with property values near the Denver Metro Area of Colorado.

Adams County, Colorado is a prime location to examine due to its complex distribution of industrial and commercial sites, "distinctive odor," and its proximity to the Denver Metro area (Hibberd, 2002). Housing data from the Adams County Assessor's Office provided the dependent variable of housing price and controls on housing attributes. The data includes housing sales in Adams County from the 1990's and on. Data on pollution has been compiled from ground-proofing sessions, the Toxic Release Inventory (TRI) and building codes acquired from the assessor's data to control for non-polluting industrial sites. The TRI data is measured and reported by the EPA and captures a wide verity of industries. The main variables of interest is the cumulative count of noxious and carcinogenic pollutants or polluting sites within a radius of single family homes. In addition, industrial and commercial controls of the same nature are leveraged to understand how concentrated industrial and commercial sites impact housing values.

My research aims to minimize omitted variable bias by carefully observing industrial and commercial properties, examining the disaggregated effects of noxious and carcinogenic pollutants, and using different statistical methods to gain a better understanding of the relationship between pollution and housing prices in this area. With guidance from previous work and institutional knowledge gained from ground-proofing, I have create the beginnings of a framework to measure the damage done to a socio-economically disadvantaged and predominantly minority group of people.

2 Literature Review

2.1 Economic Background

To understand the impacts of pollution in this area, I performed a hedonic price model and a repeat sales framework analysis. The hedonic price model (HPM), as formalized by Rosen in 1974, forms the basis for the first empirical test for environmental discrimination. The HPM model uses the standard assumptions that a composite good, such as a house, is comprised of characteristics, each with its implicit price, which contribute to the total house value (Hite, 2008). The model boils down to a competitive equilibrium on a plane of many different dimensions. These dimensions are a vector of qualities. These can be applied to a house, and the commodities offered must equal the amount demanded by the consumer that chooses to live there (Rosen, 1974). The hedonic price model has been applied to understand what each characteristic is worth. The market price for the ith house can be written as

$$P_i = P(c_{i1}, c_{i2}...c_{in}) \tag{1}$$

Where P_i is the price of a home and c_{in} is the nth attribute of the house. This model can also be applied to environmental disamenities (Taylor, 2008). However, The hedonic price model has been criticized by some researchers for a series of econometric problems that can lead to the bias of estimation, like spatial heterogeneity, spatial autocorrelation, housing quality change, multicollinearity, and heteroscedasticity (Greenstone & Gallagher, n.d.) (Rosen, 1974) (Baranzini, Ramirez, Schaerer, & Thalmann, 2008) (Taylor, 2008). Sorting or heterogeneity across individuals tastes for clean environments is also an issue not accounted for in the hedonic model. This can bias coefficients and under estimates the value of pollution as illustrated in Chay and Greenstone (2005).

Thus, the hedonic price model alone is not enough to fully examine the relationship because it is sensitive to time-invariant unobservables and may lead to a perverse coefficients Chay and Greenstone (2005). An alternative method to help limit omitted variable bias would be the Repeat Sales Framework. The repeat sales method was proposed by Bailey, Muth and Nourse in 1963 (OECD

et al., 2013). This method tracks the change in price of real estate between a current sale previous sales. Since the method follows a house in time, housing characteristics that do not vary overtime do not need to be accounted for; this eliminates unobservables in time-invariant qualities. However, a major pit fall of this method is that a house must be sold more than once during a given time period. Nonetheless, a repeat sales model is still useful to limit the issues seen in a hedonic price model alone.

2.2 Institutional Knowledge

The Suncor oil refinery is one of the largest polluters in the Denver metro area. Recent incidents in 2016 and 2017 have had noxious consequences. In 2016, a sizable orange smoke plume was emitted from the refinery, which forced nearby residents into their homes to avoid adverse health effects (Minor, 2017). Similarly, in March 2017, flames shot out of the refinery and caused a local road closure (Minor, 2017). Suncor also has a history of harmful incidents. In 2011 and 2012, Suncor spilled over 785,000 gallons of pollutants into Sand Creek, resulting in extremely high benzene levels (Minor, 2017). Extreme exposure to benzene has been linked to cancer and aplastic anaemia (World Health Organization, 2010).

Unfortunately, Suncor is not the only major source of pollution in the area, as of 2015 there are 42 active TRI sites. Communities living in the county are exposed to high concentration of environmental disamenities, this exposure could be considered an example of environmental injustice. According to census data collected by Earthjustice, Adams County has a population of over 50,000 people, 46% of which are of Latinx heritage. They note that the areas closer to the oil refinery have higher concentrations of minority residents. In addition, 20% of children in Commerce City live below the poverty line. Adams County as a whole is only 38% Latinx and 19.9% low-income (Minor 2017). Commerce City and nearby areas in Adams County could be an example of environmental injustice.

There may be a case of environmental injustice given the demographics and polluting activities in the area, however the focus of this paper will examine the impacts of pollution in this area rather than using economic methods to prove housing discrimination exists (Hite, 2008). A hedonic and repeat sales framework has not been conducted in Adams County before. While this is a

locational distinction, there are also method-related contributions associated with this project. After examining research conducted on this topic, I do not believe a comprehensive analysis has been conducted using TRI sites, and non-specified industries. While each of these methods have been assessed separately, to the best of my knowledge they have not been used in conjunction on a single location.

3 Data

3.1 Toxic Release Inventory Data

To capture the level of pollution and polluting industries, Toxic Release Inventory (TRI) Data for Adams County was leveraged. Historically, collection of the TRI was prompted by the release of methyl isocyanate gas from Union Carbide Chemical plant in Bhopal in 1985. The TRI is updated annually and is reported to the EPA from facilities. The inventory includes chemicals that are linked with cancer or other chronic and acute human health issues, and environmental effects.

The data includes observations from 1987-2015. There are between 19-42 registered sites in the county and 4,154 company level observations. The data includes latitudinal and longitudinal co-ordinates, site name, industry sector, on site release totals, various pollutants and their quantities, and lastly their total release. The data regarding pollutant specific information has been levered to generate an odor variable. According to the Agency for Toxic Substances and Disease Registry, there are many oder-producing substances that are related to certain industries. These industries include: paper mills, textiles, rubber manufacturers, wood treatment facilities, and petroleum refineries. These industries are associated with odor producing substances like Pentachlorophenol creosote, hydrogen sulfide, sulfur oxides, benzene, xylene, and toluene (Atsdr, n.d.). All of these chemicals are observed in the TRI data and a noxious indicator was generated to capture the smell associated with the TRI Sites. The noxious variable is the cumulative count of the noxious pollutants released near a home. A similar variable noting carcinogenic pollutants was native to the raw dataset. While some authors work use human test subject to measure odor in these types of studies, by leveraging the ATSDR information I generated a historical variable for smell (Eyckmans, De Jaeger, & Rousseau, 2011).

While the TRI is an excellent source of data to determine how much firms are polluting, not all facilities are required to report to TRI. Facilities typically included in the inventory are: larger manufacturing, metal mining, electric power generation, chemical manufacturing and hazardous waste treatment sites. Companies are sorted according to the North American Industry Classification System (NAICS). While these codes are updated every five years, during a ground-proofing session conducted in November of 2017 it was clear that the TRI was not a complete data source the majority of industrial activities. Companies like Omega Industrial Products, Amerigas, Rasaite, Eaton Metal Products, and a Waste Management facilities were not included in the TRI even though they exist within the county and have some capacity to pollute (O. T. US EPA OEI, n.d.).

However, even if all polluting industries were included in the TRI data, the companies report it directly to the EPA. This gives opportunities for polluting companies to adjust their reporting methods, which would lead to a collection bias. However, other papers have used the TRI as a means to measure pollution and its impact on housing prices (Mastromonaco, 2013). Ignoring the possible collection bias, there has also been a notable difference between the effects of polluting industries and non-polluting industries and to capture this issue, non-TRI sites must be accounted for (Taylor, 2008). This is why I leveraged the Adams County Assessors Data to create an industrial and commercial variable to represent the cumulative count of those sites near a home.

3.2 Adams County Assessors Data

The dependent variable fir this analysis is the natural logarithm of sales price. This data is from county level assessor's data graciously provided by the Adams County Assessor's Office and formatted by Margaret Grondalski. There are 577,471 sales records dating from 1901 to 2017.There are 143,497 properties in the raw dataset. The raw sales data has an average property price of $511,814. Each observation in the assessors data set is a sale of a home that includes year sold, month sold, location, type of property, price, and in some cases number of bedrooms, bathrooms, square-feet, stories and other housing characteristics. In addition to leveraging sales over time and house characteristics, we can use the classification in the Adams County assessor's data to include other industrial sites that are not captured in the TRI. The assessors categorize properties by commercial, industrial, and residential. By creating these variables, I limit the bias associated with

agglomeration (Billings & Johnson, 2016). During my ground proofing session, I saw that many industrial sites are grouped with TRI sites. For example: Suncor Oil Refinery had an asphalt manufacturer, concrete manufacturer, and a roofing suppler within a short distance. In addition, there is a Walmart, Chipotle, and various other commercial sites on the opposite side of the highway.

3.3 Summary Statistics

There are different data sets for the hedonic and repeat sales methods due to data limitations. Not every sale included housing characteristics so the hedonic data set has 256,092 observations while the repeat sales data has 447,624 observations. There are some differences associated with each data set. The repeat sales data set has an average longitudinal coordinate of -104.909 and Latitudinal coordinate of 39.88976. The repeat sales data set has an average longitudinal coordinates of -104.9164 and Latitudinal coordinate of 39.88325. While these discrepancies are small there is some difference in the locational mean of each data set. On average the mean sales price of the hedonic data set is 38% larger than the repeat sales data as we see in Table 3. However both samples increases in price the further away a TRI Site from the home. Regardless of these differences, average exposure of homes is relatively similar. As illustrated in Table 7, average exposure to TRI Sites by radius has little variation between hedonic and repeat sales data. A similar trend is seen in the other pollutant variables. The most notable difference between the two samples is the number of houses exposed to at least one of the polluting or control sites. The pollution and site variables are separated into 8 gradients. These include .05 km, 1 km, 1.5 km, 2 km, 2.5 km, 3 km, 4 km, and 5 km. The decision to use distance groupings was informed by Taylor, Phaneuf, and Liu (2016). The gradation was informed by the ground proofing session, these groups are an approximation to understand how house across the street, down the road, in the same neighborhood, and a couple miles down the road were impacted by TRI Sites and pollution.

On average from 1990-2015 TRI sites omit 4 pollutants each. However, one single site emitted up to 27 different pollutants in a given year. As seen in Figure 1, there has been an overall increase in TRI sites overtime. There is a peak in TRI sites 2004 then a gradual drop and in 2009 the number of TRI site increases into 2015. In 2015, there are 42 active TRI Sites. The variation in the TRI Data could be coming from different sources; either the change in sites is due to the creation

and closure of polluting industries, or the EPA changes their restrictions on what is considered a TRI site year to year. I believe the case is a mixture of both. However, the largest companies like Perunia and Suncor have observations for every year, so there are limited concerns of extreme collection errors in the TRI data. In contrast to number of TRI Sites increasing overtime, there seems to be a level number of emissions per company by year. According to Figure 2, the lowess smoother trend levels out around 4 emission per company. However, the larger outliers seem to be increasing overtime. This observation makes scene since companies like Suncor and Perina had increase in emissions over time.

The hedonic data set has housing characteristics like: number of bedrooms, bathrooms, stories, age, and square-footage. According to table 4, the average number of bedrooms is 3, bathrooms is 2, stories is 1.5. The average year built is 1990 and age is 26 years, total square feet averages at 1,675, and on average a house sold 2.2 times between 1990-2015. These average features align with the observations made during the ground proofing session nn 2017. Most of the houses were one story ranchers and smaller single family homes. The repeat sales data does not have housing characteristics because the method relied on properties being sold more than once and examines the difference between those sales to estimate the coefficients. The average number of sales between 1990-2015 is 2.93 in the repeat sales sample. However, there is a slight correlation between price and number of times a home is sold in this sample, as illustrated in Table 6, there is a slight correlation of -.0501 between price and number of times sold. This suggests that houses with a lower price sell more often, however this correlation is not very strong. Overall, both data sets exibit the same trend between distance from a polluting industry and price. In table 3 we can see that both samples exhibit an increase in price when the distance groupings increase in radius. They both exhibit steep increase in price at first then taper off into smaller increases in price after the 3 km mark. This relationship in the descriptive statistics mirrors what would be expected in real life and in the regressions.

4 Methodology

4.1 Hedonic

Equation (2) is the first model for testing the relationship between general, noxious, and carcinogenic emissions from a TRI site and housing prices. The depended variable, $LnPrice_{it}$ is the natural log of the sales price observed on and individual house in time period t. $triem_{it}$ is the cumulative count of the TRI emissions within a radius of an individual home i in time period t. nox_{it} is the cumulative count of noxious pollutants emitted within a radius of an individual home i in time period t. $carc_{it}$ is the cumulative count of carcinogenic pollutants emitted with in a radius of an individual home i in time period t. $indust_{it}$ and com_{it} are the industrial and commercial sites observed within a radius of an individual house i in time t. The term $\gamma\ x_i$ denotes the vector of housing characteristics of house i. It includes the following variables: number of bedrooms, bathrooms, stories, age, per 1000 square-feet and region. For more information refer to table 1. δ_{my} refers to a fixed effect for the month and year sold. This allows for seasonal variation in the housing market. The month and year fixed effects would also take into account any shocks the 2008 housing crisis created in this market. In addition, the model also has regional and yearly fixed effects denoted as ρ_{ry}. This allows for each region to have their own trends overtime. For example, the urban regions may see a steeper change in prices overtime that is not associated with pollution, the regional and yearly fixed effect helps account for this. Equation (2) also includes clustered standard errors on the individual housing level. All subsequent equations also include clustered standard errors.

$$LnPrice_{it} = \alpha + \beta_1 \text{triem}_{it} + \beta_2 \text{nox}_{it} + \beta_3 \text{carc}_{it} + \beta_4 \text{indust}_{it} + \beta_5 \text{com}_{it} + \gamma\ x_i + \delta_{my} + \rho_{ry} + \varepsilon_{it}, \quad (2)$$

I will be taking a look at how TRI emission impact housing prices, but also how the existence of a TRI site impact housing prices. In the second model the tri_{it} variable denotes the existence of a TRI Site within a certain radius of a individual i home, in time period t. The second model will

be examining the relationship between noxious and carcinogenic pollutants holding the number of TRI and other sites constant. Including TRI sites in the analysis will help control and understand how a view of a physical site may impact housing prices. Baranzini and Schaerer (2011) worked to understand the relationship of eye sores using GIS technology to indicate weather a view of the Rocky Mountains was hindered, the existence of a TRI Site maybe a crude proxy to control for eye sores associated with a site.

$$LnPrice_{it} = \alpha + \beta_1 \text{tri}_{it} + \beta_2 \text{nox}_{it} + \beta_3 \text{carc}_{it} + \beta_4 \text{indust}_{it} + \beta_5 \text{com}_{it} + \gamma\ x_i + \delta_{my} + \rho_{ry} + \varepsilon_{it}, \quad (3)$$

4.2 Repeat Sales

Unlike the hedonic model, the repeat sales method uses panel data instead of cross sectional observations. Since my average sale per home is approximately 3 as seen in Table 5, a repeat sales analysis can be conducted with limited worry of omitting too many observations. Similar to the hedonic model, the depended variable is $LnPrice_{it}$ is the natural log of the sales price observed on and individual house in time period t. $triem_{it}$ is the cumulative count of the TRI emissions within a radius of an individual home i in time period t. nox_{it} is the cumulative count of noxious pollutants emitted within a radius of an individual home i in time period t. $carc_{it}$ is the cumulative count of carcinogenic pollutants emitted with in a radius of an individual home i in time period t. $indust_{it}$ and com_{it} are the industrial and commercial sites observed within a radius of an individual house i in time t. It also has the δ_{my} fixed effect, however instead of a vector of housing characteristics, it has a parcel fixed effect of γ_i. Since I assume these characteristic do not change for an individual house overtime any vector of housing characteristics drop out due to multi-collinearity.

$$LnPrice_{it} = \beta_1 \text{tri}_{it} + \beta_2 \text{nox}_{it} + \beta_3 \text{carc}_{it} + \beta_1 \text{indust}_{it} + \beta_2 \text{com}_{it} + \gamma_i + \delta_{my} + \rho_{ry} + \varepsilon_{it}, \quad (4)$$

For the 4th model, instead of accounting for the general pollutants emitted from a TRI site, I will be examining tri_{it}, which is the existence of a TRI Site within a certain radius of a individual i

home, in time period t. Like the second model examines the relationship between noxious and carcinogenic pollutants holding the number of TRI sites and other sites constant, the 4th model will be doing the same except using the repeat sales method.

$$LnPrice_{it} = \beta_1 \text{triem}_{it} + \beta_2 \text{nox}_{it} + \beta_3 \text{carc}_{it} + \beta_1 \text{indust}_{it} + \beta_2 \text{com}_{it} + \gamma_i + \delta_{my} + \rho_{ry} + \varepsilon_{it}, \quad (5)$$

Overall, by examining the relationship between housing prices and disaggregated pollution types and sites we can separate the effect of each type individually as general, noxious, and carcinogenic pollution may behave differently. Equations 2-5 are all variations of the disaggregated model that takes different pollutants and sites into account to control for agglomeration. The repeat sales variations will help account for omitted variable bias often observed in hedonic price models due to unobservables in a bundle of housing characteristics.

4.3 Key Assumptions for Causal Interpretations

A casual interpretation for the hedonic model hinges on the assumption that vector of observed housing characteristics and various fixed effects are exogenous. This relationship is illustrated in equation (6).

$$E[\varepsilon_{it}|triem_{ti}] = 0 \quad (6)$$

However, we know that the hedonic model is associated with sources of endogeneity like omitted variable bias. There are other factors that impact housing prices. A key assumption is the Conditional Independence Assumption (CIA). By adding the vector of housing characteristics and pollutant controls I am limiting some omitted variable bias. In order to draw a causal relationship in the hedonic model there must be no unobservables associated with the sales price of a house and the following assumptions must be applied; the expectation function is linear, there are constant effects of pollution and the unobservables are time-invariant or is common across cross-sectional

units. By including regional and yearly fixed effects and month year fixed effects this accounts for trends associated with regional growth, and market fluctuation.

A key assumption associated with the Repeat Sales Framework is common trends in absence of treatment. The houses that have never had a TRI Site or noxious and carcinogenic releases near them have to have common trends in housing prices. If there are common treatment effects then the coefficients in equations (4) and (5) reflect the average effect of an additional pollutant or polluting site. To draw a causal interpretation from the Repeat sales model, I assume that housing price is conditionally exogenous of pollution metrics, that all unobservables are time-invariant, and changes in pollution variables randomly vary across houses overtime.

5 Interpretation

5.1 Hedonic

Since there are multiple distance groupings in each table, I will focus on the 1.5 km group for easy interpretation. This grouping is an ideal distance to look at since 1.5km is about a mile and the distinctions between noxious and carcinogenic pollutants would matter. In addition, most people could be able to see and know of industrial and commercial sites within that distance easily. Table 10 illustrates the results for equation (2). The interpretations for the 1.5 km distance grouping are as follows: the hedonic model with all controls defined in equation (2) that an additional general emission from a TRI site has a 0.7% decrease on housing prices. Carcinogenic pollutants have 3% decrease on housing prices, however noxious pollutants have a positive and insignificant impact of 0.14% increase on housing prices. An additional industrial site has a 0.6% decrease on housing prices, and an additional commercial site has a 0.2% decrease on housing prices. There are perverse signs associated with commercial sites and noxious pollutants in this model.

Table 13 illustrates the results for equation (3). The interpretations for the 1.5 km distance grouping are as follows: An additional TRI site within that distance grouping is associated with a 6.2% decrease in housing prices. Carcinogenic 4.6% increase on housing prices, noxious has an insignificant and very small coefficient indicating a .089% increase on housing prices for every additional noxious gas. An additional industrial site has a .41% decrease and an additional commercial site has

a 0.2% decrease on housing prices. This model also has a perverse relationship between commercial sites, noxious, and now carcinogenic pollutants.

5.2 Repeat Sales Model

Table 17 illustrates results for equation (5). The 1.5 km distance grouping interpretations are as follows: General TRI Emissions has a 6.7% increase on housing prices, an additional noxious pollutant is associated with a 18% decrease, and an additional carcinogenic pollutant has a 12% decrease, an additional industrial site is associated with a 3% decrease in housing prices, and an additional commercial site is associated with a .5% increase. The reason for the positive relationship between an additional general emission from a TRI site and housing prices could be due to a violation with the assumption of no collinearity. Noxious and carcinogenic pollutants are a subset of the general tri emissions variable.

Table 15 illustrates results for equation (4). The coefficient for an additional TRI site is insignificant, however it is associated with a 6.3% decrease in housing prices, an additional noxious pollutant is associated with a 9% decrease, an additional carcinogenic pollutant is associated with a 5% decrease; however this coefficient is insignificant. An additional industrial site within a 1.5 km radius is associated with a 3% decrease and an additional commercial site is associated with a 0.5% increase in housing prices. Overall, I expect the 4th model to be the best representation of the true relationships between pollutants and housing prices because it uses the cumulative count of TRI sites instead of their general emissions.

Other authors suggest that odor nuance can lead to a 5% decrease in home value, and heavily affected zones suffered almost a 12% decrease in value (Eyckmans et al., 2011). My 1.5 km estimates for odor nuance using historical data falls within that threshold at a 9% decrease in housing prices. Overall, the carcinogenic and TRI sites contribute a total of 10.3% in the 1.5 km range, Chay and Greenstone (2005) states that a meta-analysis of 37 concluded that there is an 11% decrease associated with decreasing pollution.

5.3 Model Comparisons

On average, in the TRI Site Models in the the hedonic analysis or equation (2) underestimated the TRI Site coefficient by .02 points or by 2% effect on housing price as seen in tables 10 and 17. On average, the hedonic model underestimated the coefficient on carcinogenic by .098 or 9.8% effect on housing prices. In addition, the hedonic model underestimated the noxious coefficient by .07 points or 7% effect on housing prices. These observations in my results align with other work stating that the hedonic models tend to underestimate the coefficients of pollution. In table 10 carcinogenic pollutants have a very strong positive coefficient after accounting for industrial, commercial, and tri emissions. This is likely not the case in the real world. In addition, the hedonic model with TRI Sites indicate a positive relationship between TRI Sites and housing prices. The coefficient for commercial sites in the hedonic shows a perverse sign as well.

Focusing on the repeat sales method, we see that adding commercial and industrial site controls the coefficient for TRI sites decrease by .04 on average. The model without these controls overestimates the impact of TRI sites. This was an expected outcome of adding industrial and commercial controls since industrial and commercial sites tend to cluster around TRI sites in Adams County. After disaggregating pollutant types by separating them into noxious and carcinogenic categories, there was an average decrease in the TRI Site coefficient of .01. The disaggregated repeat sales model for TRI Sites referenced in Equation (4) exhibits and interesting relationship with TRI Sites and price in closer proximities to homes. In between .05 KM and 2.5 KM the coeffecent for TRI Sites is insignificant while the noxious and carcinogenic variables hold a negative relationship. This suggests that people who live closer to TRI Sites may care more about additional pollutants than another TRI Site. However, this result may be due to the limited number of houses with TRI Sites in close proximity within those distance groupings.

The coefficients on noxious and carcinogenic in both repeat sales models hold a negative and decreasing trend. At first, one additional noxious pollutants has a greater impact on housing values than carcinogenic. For the TRI emissions model, carcinogenic becomes more impactful than noxious pollutants at the 3 km mark. The same relationship is evident in the TRI Site model, however this switch in coefficient magnitude happens at the 2.5 km mark.

For the disaggregated repeat sales model for general TRI emissions for equation (5) and table 17, the difference in TRI coefficient is steeper. The initial change in the TRI coefficient when adding industrial and commercial site controls decreases by .03. However, after controlling for noxious and carcinogenic pollutants the coefficient for TRI emissions becomes positive. This could be due to collinearity issues since the TRI emissions variable contains all types of pollutants from TRI Sites. Across the repeat sale model iterations the coefficient for commercial sites remained relatively constant when control groups were added. In both TRI Site and TRI Emissions models the coefficient for commercial for a home within .05 KM was .19. This means that an additional commercial site within a .05 KM distance would increase sales price on average by 1.9%. There is a concave relationship between housing price and additional commercial sites.

5.4 Average Comparisons

Regardless of minor inconstancies at the distance grouping levels, there are some major patterns to behold. The following average results are derived from table 15 for equation (4): On average, accords all distance groupings the average effect of an additional TRI Sites on housing prices is a 1% decrease, an additional noxious pollutant has a 7% decrease on housing prices, an additional carcinogenic pollutant has 6% decrease on housing prices, an additional industrial site has a 3% decrease on housing prices, and on average across all distance groupings commercial sites have a .05% increase on housing prices. On average across all distance groupings the average effect of an additional general TRI emission has a 5% increase on housing prices, an addition noxious chemical has a 13% decrease on property values on average, an additional carcinogenic pollutant has a 9% decrease in housing prices, an additional 3.7% increase on housing prices, and an additional commercial site has a .57% increase on housing prices across all distance groupings. There are surprising consistencies between the models with respect to commercial and industrial site coefficients. In addition, the average effect across distance groupings for noxious pollutants is greater than carcinogenic pollutants. While these are just average coefficients and relationships among all distance groupings, is can help illustrate a common trend when comparing the disagergated model.

6 Discussion

To further this research, I would recommend examining spacial auto correlation within the data. To help adjust for any spacial correlation, instead of doing parcel level cluster standard errors, census tract data would be more appropriate. This will allow for neighborhoods to have different standard errors rather than just an individual house. In addition to clustering standard errors by census tract, I would suggest running ANOVA tests to see if the full disaggregated model is statistically different than the secondary model without noxious and carcinogenic controls.

6.1 Other Data Considerations

Other authors preform a similar analysis on National Priorities or Superfund sites (Kiel & Williams, 2007; Taylor, 2016). There are a few notable active National Priorities in Adams County. NPLs may have a different effect than other industrial sites so it is important to include their existence in further research. The more notable sites are: Vasquez Blvd, Rocky Mountain Arsenal, and Broderick Wood. Vasquez Boulevard and I-70 was the site of two smelting plants in the 1870s which refined gold, silver, copper, lead and zinc. As a result, heavy metals were deposited in area soils at levels that impacted the groundwater and posed a health risk to local communities in come cases (US EPA, 2017). Broderick Wood is a wood treatment facility that was operational between 1947-1982. They used creosote and pentachlorophenol (PCP) on various wood products with poor disposal practices. As a result they contaminated soil and groundwater with hazardous chemicals (US EPA, 2017). Rocky Mountain Arsenal was established by The U.S. Army in 1942. Rocky Mountain Arsenal was used to produce incendiary munitions and chemical warfare agents like mustard gas. After the war it was leased to Shell Chemical Company to promote economic growth. Shell produced agricultural pesticides on site from 1946-1982. These activities resulted in environmental contamination over time (US EPA, 2017). Generating a thoughtful variable to capture these sites would help control for their impacts on housing prices.

Prevailing Wind Data was also a key part in other analysis. There are two main stations that record prevailing wind data in Adams County, Buckley Air Force Base Airport and Denver International Airport. These are the two closest stations to the center of pollution. For the most part, winds are

southerly and mild. However, DIA has a slight southwesterly wind pattern. This may be due to the strong Westerly winds recorded at the KBJC: Broomfield / Jeffco station located near Rocky Flats. While on average, winds seem to be relatively calm, at the Buckley Air Force Base Airport the frequency by direction is southerly with about a 10% frequency. This direction rarely surpasses a wind speed of 10 kts per hour. The DIA station is less stable. They record more South-Westerly winds on average with a 5% frequency. In addition, the Northerly winds have a higher speed just below 15 kts per hour (Wind History). While there doesn't seem to be much significance with these wind patterns given their frequency and speed, more research is needed to properly account for their effects. Since my method of measuring pollutant exposure fails to account for drastic changes in pollution in smaller areas or the wind-driven dispersion of pollutants, a paper explores the use of an atmospheric dispersion model (Sullivan et al., 2017).

7 Conclusion

In conclusion, there seems to be an overall negative association with TRI Sites and pollutants with property values in Adams County Colorado. Noxious chemicals seem to have a larger and more significant impact the closer a home is to the pollution. However, carcinogenic pollutants seem to matter more than noxious pollutants as the distance increases. Results indicate that pollutant coefficients in the repeat sales model are higher than the hedonic coefficients. Overall, the effect of an additional TRI Sites on housing prices within a 1.5 km radius is a 6.3% decrease, an additional noxious pollutant has a 9% decrease, an additional carcinogenic pollutant contributes a 5% decrease, an additional industrial site has a 3% decrease on housing prices. There is still much more to consider when working to understand be relationship between noxious and carcinogenic pollutants in Adams County Colorado. Even more so, there are other sources of pollution, controls, and statistical methods that could be applied to this data set. One major pitfall of my analysis is that it ignore spacial correlation, more research is needed to get a better understanding of the relationship of between housing prices and pollutants in Adams County Colorado.

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9 Tables & Figures

Table 1: Glossary of Control Variables

Housing Characteristic Controls	**Description**
Bedrooms	Number of bedrooms in a house
Bathrooms	Number of bathrooms in a house
Stories	Number of stories in a home
1000 Square Feet	Total square feet divided by 1000
Age	How old the house was at time of sale
Region	Either Rural, Mixed, or Urban. There are 5 regions total
Geographic Controls	**Description**
Industrial	Cumulative Count of Industrial Sites
Commercial	Cumulative Count of Commercial Sites

Table 2: Glossary of Pollution Variables

Pollution Variables	**Description**
TRI Sites	Cumulative Count of TRI Sites
TRI Emissions	Cumulative Count of TRI Pollutant Emitted
Carcinogenic	Cumulative Count of Dangerous TRI Pollutant Emitted
Noxious	Cumulative Count of *Smelly* TRI Pollutant Emitted

Table 3: Comparative Summary Statistics

Hedonic Data						
Variable	**.5 KM**	**1 KM**	**2 KM**	**3 KM**	**4 KM**	**5 KM**
Mean Sales Price	205517	241554.1	310672.9	398913.9	404424	414602.1
% difference	15%	22%	22%	1%	2%	
Repeat Sales Data						
Variable	**.5 KM**	**1 KM**	**2 KM**	**3 KM**	**4 KM**	**5 KM**
Mean Sales Price	116622.5	172352	196272.9	228506.6	242364.2	249438.5
% difference	32%	12%	14%	6%	3%	

Table 4: Hedonic: Average Housing Characteristics

Variable	**Average**
Bedrooms	3
Bathrooms	2
Stroies	1.5
Year Built	1990
Age	26
Total Square-feet	1675
Sales	2.2

Variable	**Number of Observations**
Sales	263,805

Table 5: Repeat Sales: Average Housing Characteristics

Variable	**Average**
Sales	2.93

Variable	**Number of Observations**
Sales	447,624

Table 6: Correlation Between Number of Sales and Housing Price

Variable	**Repeat Sales**	**Hedonic**
salep	-0.0782	-0.0067
lnsalep	-0.0501	-0.0052

Table 7: Comparative Exposure Summary

Hedonic: Average Exposure						
Variable	**.5 KM**	**1 KM**	**2 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	1.079	1.268	1.571	2.156	2.715	3.118
TRI Emissions	3.463	3.833	4.765	7.143	9.307	13.095
Noxious	3.068	3.565	3.984	5.605	6.967	9.280
Carcinogenic	1.800	1.979	2.318	3.213	4.053	5.256
Industrial	2.403	4.807	9.256	14.506	20.048	26.596
Commercial	8.127	22.600	73.399	148.701	239.429	354.590
Hedonic: Houses Exposed						
TRI Sites	1,667	12,219	52,544	94,025	134,046	154,421
TRI Emissions	1,677	12,244	52,586	94,076	134,133	170,046
Noxious	1,321	9,507	42,903	80,971	117,694	155,111
Carcinogenic	381	4,078	23,463	47,141	72,807	102,946
Industrial	12,370	39,557	100,182	144,686	185,681	220,734
Commercial	100,535	174,530	231,246	244,548	252,296	254,270
Repeat Sales: Average Exposure						
Variable	**.5 KM**	**1 KM**	**2 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	1.067	1.246	1.598	2.211	2.786	3.209
TRI Emissions	3.125	3.606	5.006	7.729	10.032	14.192
Noxious	2.7	3.331	4.177	5.977	7.377	9.908
Carcinogenic	1.633	1.801	2.380	3.431	4.329	5.646
Industrial	2.592	4.559	8.843	14.404	20.49	27.741
Commercial	8.675	24.857	81.492	166.44	269.856	396.866
Repeat Sales: Houses Exposed						
TRI Sites	4,015	24,431	102,240	179,347	259,429	298,671
TRI Emissions	4,038	24,500	102,348	179,486	259,681	329,253
Noxious	3,334	18,523	81,038	154,093	229,181	301,409
Carcinogenic	922	9,155	48,728	93,011	143,686	201,542
Industrial	23,034	77,299	185,683	263,917	331,635	389,557
Commercial	211,176	330,247	414,232	432,896	442,431	444,756

*Average Exposure per home and number of homes with at least 1 occurrence within the radius

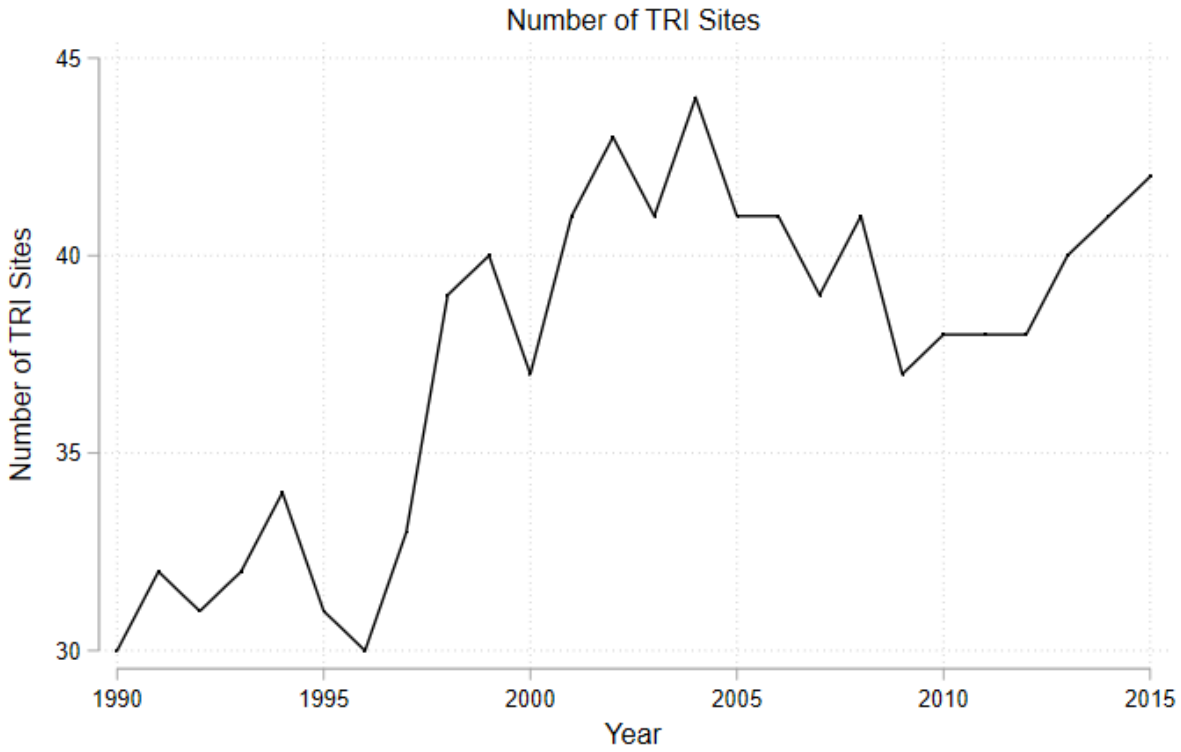

Figure 1: TRI Sites by Year

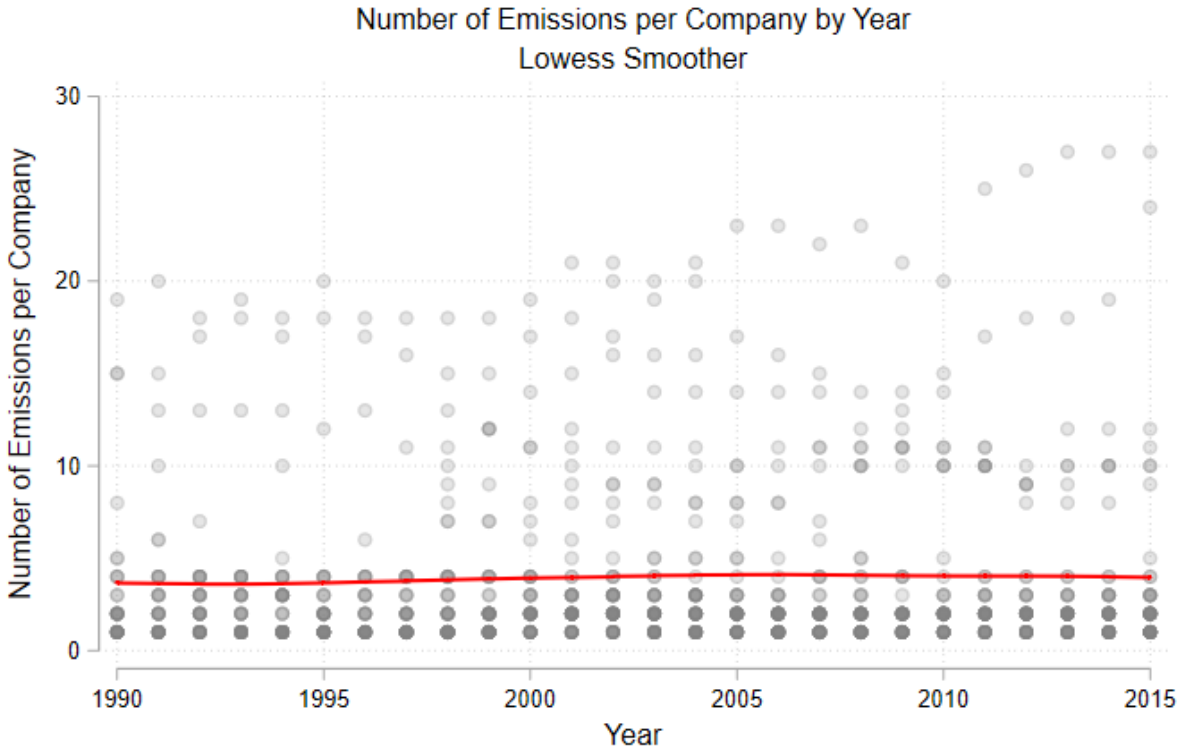

Figure 2: Number of Emissions per Company

Figure 3: Price by Year

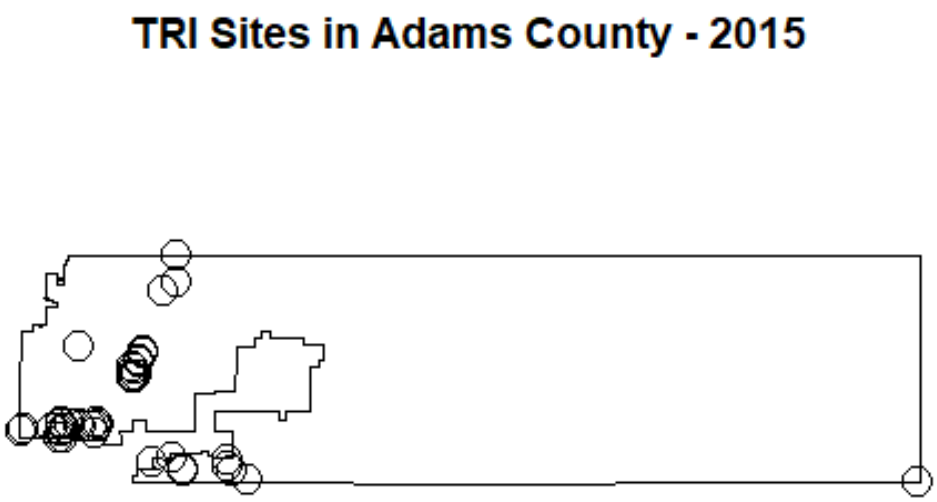

Figure 4: TRI Sites Map - 2015

Table 8: TRI Emissions: Basic Hedonic

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Emissions	0.00188	-0.00327***	-0.00397***	-0.00503***	-0.00467***	-0.00334***	-0.00262***	-0.00135***
	(0.00231)	(0.00107)	(0.00067)	(0.00043)	(0.00028)	(0.00021)	(0.00016)	(0.00013)
bedrooms	-0.0490***	-0.0491***	-0.0489***	-0.0490***	-0.0490***	-0.0490***	-0.0497***	-0.0494***
	(0.00356)	(0.00356)	(0.00356)	(0.00355)	(0.00355)	(0.00356)	(0.00355)	(0.00356)
baths	0.0403***	0.0406***	0.0406***	0.0402***	0.0392***	0.0385***	0.0371***	0.0376***
	(0.00349)	(0.00350)	(0.00349)	(0.00349)	(0.00349)	(0.00349)	(0.00350)	(0.00351)
stories	0.0118**	0.0122**	0.0129**	0.0131**	0.0129**	0.0128**	0.0128**	0.0135**
	(0.00547)	(0.00548)	(0.00549)	(0.00548)	(0.00547)	(0.00547)	(0.00547)	(0.00548)
age	-0.000116***	-0.000116***	-0.000117***	-0.000118***	-0.000121***	-0.000121***	-0.000124***	-0.000121***
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
sqft/1000	0.496***	0.496***	0.495***	0.495***	0.494***	0.495***	0.496***	0.496***
	(0.00561)	(0.00561)	(0.00562)	(0.00561)	(0.00560)	(0.00560)	(0.00560)	(0.00560)
region	-0.140***	-0.140***	-0.140***	-0.140***	-0.140***	-0.140***	-0.141***	-0.140***
	(0.04960)	(0.04960)	(0.04960)	(0.04960)	(0.04950)	(0.04950)	(0.04950)	(0.04950)
Constant	10.75***	10.74***	10.74***	10.74***	10.75***	10.75***	10.76***	10.75***
	(0.31200)	(0.31200)	(0.31200)	(0.31200)	(0.31200)	(0.31200)	(0.31200)	(0.31200)
Observations	233974.00000	233974.00000	233974.00000	233974.00000	233974.00000	233974.00000	233974.00000	233974.00000
R-squared	0.43000	0.43000	0.43100	0.43100	0.43100	0.43100	0.43100	0.43100
Clustered Standard Errors on the parcel level								

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: TRI Emissions Hedonic with Industry Controls

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Emissions	0.00629***	0.00413***	0.00042	-0.000232	-0.0000393	-0.000912***	-0.00189***	0.000381**
	(0.0022)	(0.0009)	(0.0007)	(0.0005)	(0.0003)	(0.0003)	(0.0002)	(0.0002)
Industrial	-0.0367***	-0.0156***	-0.00583***	-0.00334***	-0.00268***	-0.00132***	0.00	-0.000692***
	(0.0022)	(0.0006)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)
Commercial	-0.00773***	-0.00301***	-0.00212***	-0.00155***	-0.00122***	-0.000886***	-0.000525***	-0.000322***
	(0.00029)	(0.00010)	(0.00004)	(0.00003)	(0.00002)	(0.00002)	(0.00001)	(0.00001)
bedrooms	-0.0494***	-0.0479***	-0.0434***	-0.0409***	-0.0388***	-0.0397***	-0.0412***	-0.0423***
	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0036)
baths	0.0328***	0.0298***	0.0318***	0.0357***	0.0390***	0.0412***	0.0448***	0.0484***
	(0.0035)	(0.0035)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0035)	(0.0035)
stories	0.006	0.003	-0.008	-0.0131**	-0.0147***	-0.00962*	-0.006	0.004
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
age	-0.000132***	-0.000125***	-0.000115***	-0.000105***	-9.90e-05***	-9.76e-05***	-9.47e-05***	-9.15e-05***
	(0.00004)	(0.00004)	(0.00004)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00004)
sqft/1000	0.486***	0.471***	0.460***	0.449***	0.443***	0.445***	0.453***	0.455***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
region	-0.141***	-0.142***	-0.143***	-0.143***	-0.143***	-0.142***	-0.142***	-0.139***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Constant	10.79***	10.81***	10.83***	10.84***	10.83***	10.82***	10.80***	12.55***
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.00)
Observations	233974	233974	233974	233974	233974	233974	233974	233974
R-squared	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.07

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 10: TRI Emissions: Disaggregated Hedonic

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
Emissions Sites	0.0381***	0.0162***	-0.00756**	-0.0167***	-0.0234***	-0.0423***	-0.0312***	-0.0184***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Carcinogenic	-0.02	0.0495***	0.0346***	0.0325***	0.0494***	0.0539***	0.0451***	0.0350***
	(0.034)	(0.010)	(0.006)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)
Noxious	-0.0401***	-0.0299***	0.0014	0.0138***	0.0184***	0.0422***	0.0267***	0.0156***
	(0.0135)	(0.0058)	(0.0038)	(0.0029)	(0.0024)	(0.0020)	(0.0014)	(0.0011)
Industrial	-0.0365***	-0.0153***	-0.00622***	-0.00391***	-0.00366***	-0.00195***	-0.000278*	-0.00107***
	(0.0023)	(0.0006)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0001)
Commercial	-0.00774***	-0.00304***	-0.00212***	-0.00153***	-0.00120***	-0.000898***	-0.000544***	-0.000345***
	(0.00029)	(0.00010)	(0.00004)	(0.00003)	(0.00002)	(0.00002)	(0.00001)	(0.00001)
bedrooms	-0.0495***	-0.0480***	-0.0433***	-0.0406***	-0.0382***	-0.0371***	-0.0383***	-0.0408***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
baths	0.0328***	0.0300***	0.0319***	0.0357***	0.0381***	0.0391***	0.0392***	0.0442***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
stories	0.006	0.003	-0.009	-0.0130**	-0.0139**	-0.00938*	-0.003	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
age	-0.000132***	-0.000124***	-0.000114***	-0.000105***	-9.99e-05***	-9.85e-05***	-9.74e-05***	-9.28e-05***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
sqft/1000	0.486***	0.470***	0.459***	0.447***	0.438***	0.439***	0.446***	0.448***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
region	-0.141***	-0.142***	-0.143***	-0.143***	-0.143***	-0.142***	-0.142***	-0.139***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Constant	10.78***	10.82***	10.83***	10.84***	10.84***	10.82***	10.81***	10.79***
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)
Observations	233974	233974	233974	233974	233974	233974	233974	233974
R-squared	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 11: TRI Sites: Basic Hedonic

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	-0.0363**	-0.0851***	-0.0628***	-0.0505***	-0.0343***	-0.0239***	-0.0160***	-0.0106***
	(0.0163)	(0.0049)	(0.0029)	(0.0021)	(0.0015)	(0.0011)	(0.0009)	(0.0008)
bedrooms	-0.0491***	-0.0491***	-0.0486***	-0.0482***	-0.0484***	-0.0487***	-0.0496***	-0.0494***
	(0.0036)	(0.0036)	(0.0036)	(0.0036)	(0.0036)	(0.0036)	(0.0036)	(0.0036)
baths	0.0403***	0.0407***	0.0400***	0.0395***	0.0386***	0.0377***	0.0366***	0.0369***
	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)	(0.0035)
stories	0.0117**	0.0136**	0.0151***	0.0138**	0.0133**	0.0138**	0.0139**	0.0140**
	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0055)
age	-0.000116***	-0.000119***	-0.000120***	-0.000122***	-0.000123***	-0.000123***	-0.000124***	-0.000122***
	(0.000041)	(0.000042)	(0.000042)	(0.000042)	(0.000043)	(0.000042)	(0.000042)	(0.000042)
sqft/1000	0.496***	0.492***	0.491***	0.489***	0.490***	0.491***	0.493***	0.494***
	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)
region	-0.140***	-0.140***	-0.140***	-0.141***	-0.141***	-0.141***	-0.142***	-0.141***
	(0.0496)	(0.0496)	(0.0495)	(0.0495)	(0.0495)	(0.0495)	(0.0494)	(0.0495)
Constant	10.75***	10.75***	10.75***	10.75***	10.76***	10.76***	10.77***	10.76***
	(0.3120)	(0.3120)	(0.3120)	(0.3110)	(0.3110)	(0.3110)	(0.3110)	(0.3110)
Observations	233974.0000	233974.0000	233974.0000	233974.0000	233974.0000	233974.0000	233974.0000	233974.0000
R-squared	0.4300	0.4310	0.4310	0.4320	0.4320	0.4310	0.4310	0.4310
Clustered Standard Errors on the parcel level								

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: TRI Sites: Hedonic with Industry Controls

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	0.0311**	-0.0173***	-0.0259***	-0.0258***	-0.0169***	-0.0199***	-0.0177***	-0.0102***
	(0.01510)	(0.00506)	(0.00325)	(0.00259)	(0.00210)	(0.00171)	(0.00116)	(0.00099)
Industrial	-0.0371***	-0.0142***	-0.00426***	-0.00165***	-0.00127***	0.00013	0.000923***	0.000256**
	(0.00223)	(0.00065)	(0.00038)	(0.00027)	(0.00023)	(0.00019)	(0.00014)	(0.00010)
Commercial	-0.00774***	-0.00302***	-0.00212***	-0.00155***	-0.00122***	-0.000899***	-0.000532***	-0.000333***
	(0.00029)	(0.00010)	(0.00004)	(0.00003)	(0.00002)	(0.00002)	(0.00001)	(0.00001)
bedrooms	-0.0494***	-0.0480***	-0.0432***	-0.0404***	-0.0384***	-0.0391***	-0.0408***	-0.0424***
	(0.00354)	(0.00351)	(0.00350)	(0.00349)	(0.00349)	(0.00351)	(0.00352)	(0.00354)
baths	0.0328***	0.0305***	0.0321***	0.0360***	0.0392***	0.0415***	0.0450***	0.0476***
	(0.00347)	(0.00349)	(0.00344)	(0.00342)	(0.00342)	(0.00343)	(0.00346)	(0.00350)
stories	0.00625	0.00355	-0.00749	-0.0131**	-0.0154***	-0.0105*	-0.00665	-0.00259
	(0.00542)	(0.00545)	(0.00547)	(0.00545)	(0.00545)	(0.00545)	(0.00547)	(0.00552)
age	-0.000132***	-0.000125***	-0.000115***	-0.000105***	-9.97e-05***	-9.74e-05***	-9.42e-05***	-9.47e-05***
	(0.00004)	(0.00004)	(0.00004)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00004)
sqft/1000	0.486***	0.470***	0.459***	0.448***	0.442***	0.444***	0.451***	0.455***
	(0.00558)	(0.00554)	(0.00550)	(0.00551)	(0.00550)	(0.00552)	(0.00554)	(0.00557)
region	-0.141***	-0.142***	-0.143***	-0.143***	-0.143***	-0.143***	-0.143***	-0.141***
	(0.04930)	(0.04900)	(0.04890)	(0.04880)	(0.04880)	(0.04890)	(0.04900)	(0.04920)
Constant	10.79***	10.81***	10.83***	10.84***	10.84***	10.83***	10.81***	10.79***
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)
Observations	233974	233974	233974	233974	233974	233974	233974	233974
R-squared	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 13: TRI Sites: Disaggregated Hedonic

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	0.03240	-0.0741***	-0.0621***	-0.0539***	-0.0366***	-0.0362***	-0.0261***	-0.0200***
	(0.02230)	(0.00758)	(0.00459)	(0.00341)	(0.00269)	(0.00210)	(0.00143)	(0.00117)
Carcenogenic	0.01590	0.0850***	0.0463***	0.0304***	0.0368***	0.0258***	0.0256***	0.0246***
	(0.02890)	(0.00959)	(0.00479)	(0.00340)	(0.00265)	(0.00215)	(0.00155)	(0.00109)
Noxious	(0.00356)	(0.00178)	0.00089	0.00139	-0.00397***	-0.00190***	-0.00567***	-0.00399***
	(0.00891)	(0.00288)	(0.00150)	(0.00110)	(0.00085)	(0.00071)	(0.00054)	(0.00044)
Indusrial	-0.0371***	-0.0131***	-0.00415***	-0.00199***	-0.00217***	-0.000661***	0.000260*	-0.000844***
	(0.00224)	(0.00066)	(0.00038)	(0.00028)	(0.00023)	(0.00021)	(0.00015)	(0.00012)
Commercial	-0.00774***	-0.00301***	-0.00209***	-0.00152***	-0.00120***	-0.000885***	-0.000532***	-0.000345***
	(0.00029)	(0.00010)	(0.00004)	(0.00003)	(0.00002)	(0.00002)	(0.00001)	(0.00001)
bedrooms	-0.0494***	-0.0477***	-0.0431***	-0.0401***	-0.0381***	-0.0385***	-0.0398***	-0.0410***
	(0.00354)	(0.00351)	(0.00350)	(0.00350)	(0.00349)	(0.00349)	(0.00351)	(0.00353)
baths	0.0328***	0.0300***	0.0316***	0.0359***	0.0390***	0.0406***	0.0430***	0.0464***
	(0.00347)	(0.00349)	(0.00344)	(0.00342)	(0.00342)	(0.00343)	(0.00345)	(0.00349)
stories	0.00626	0.00249	-0.00836	-0.0137**	-0.0151***	-0.00931*	-0.00415	0.00639
	(0.00542)	(0.00545)	(0.00547)	(0.00545)	(0.00545)	(0.00545)	(0.00547)	(0.00551)
age	-0.000132***	-0.000124***	-0.000114***	-0.000105***	-9.93e-05***	-9.68e-05***	-9.48e-05***	-9.25e-05***
	(0.00004)	(0.00004)	(0.00004)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
sqft/1000	0.486***	0.469***	0.458***	0.445***	0.437***	0.438***	0.444***	0.445***
	(0.00558)	(0.00553)	(0.00551)	(0.00552)	(0.00552)	(0.00555)	(0.00557)	(0.00557)
region	-0.141***	-0.142***	-0.143***	-0.144***	-0.144***	-0.144***	-0.143***	-0.140***
	(0.04930)	(0.04900)	(0.04880)	(0.04880)	(0.04870)	(0.04880)	(0.04890)	(0.04900)
Constant	10.79***	10.82***	10.84***	10.84***	10.85***	10.84***	10.82***	10.80***
	(0.31100)	(0.30900)	(0.30800)	(0.30800)	(0.30700)	(0.30700)	(0.30800)	(0.30900)
Observations	233974	233974	233974	233974	233974	233974	233974	233974
R-squared	0.43300	0.43600	0.43800	0.43900	0.44000	0.43900	0.43800	0.43700

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 14: TRI Sites: Repeat Sales Univariate and Industry Specific Controls

Univariate Repeat Sales

Variable	.5 KM	1 KM	1.5 KM	2 KM	2.5 KM	3 KM	4 KM	5 KM
TRI Sites	-0.120	-0.231***	-0.256***	-0.180***	-0.193***	-0.187***	-0.147***	-0.134***
	(0.151)	(0.054)	(0.034)	(0.026)	(0.019)	(0.015)	(0.011)	(0.010)
Constant	5.338***	5.391***	5.435***	5.452***	5.495***	5.552***	5.593***	5.597***
	(1.167)	(1.201)	(1.205)	(1.194)	(1.197)	(1.224)	(1.229)	(1.202)
Observations	350331	350331	350331	350331	350331	350331	350331	350331
R-squared	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501

Industry Controls

Variable	.5 KM	1 KM	1.5 KM	2 KM	2.5 KM	3 KM	4 KM	5 KM
TRI Sites	-0.126	-0.177***	-0.193***	-0.116***	-0.136***	-0.145***	-0.115***	-0.106***
	(0.152)	(0.055)	(0.034)	(0.026)	(0.020)	(0.016)	(0.011)	(0.010)
Industrial	-0.139***	-0.0614***	-0.033***	-0.021***	-0.014***	-0.009***	-0.011***	-0.013***
	(0.019)	(0.007)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Commercial	0.0193***	0.00895***	0.006***	0.004***	0.003***	0.002***	0.002***	0.001***
	(0.002)	(0.001)	0.000	0.000	0.000	0.000	0.000	0.000
Constant	5.371***	5.263***	5.359***	5.355***	5.363***	5.387***	5.515***	5.805***
	(1.199)	(1.211)	(1.249)	(1.148)	(1.113)	(1.136)	(1.120)	(1.046)
Observations	350331.0	350331.0	350331.0	350331.0	350331.0	350331.0	350331.0	350331.0
R-squared	0.134	0.134	0.134	0.134	0.135	0.135	0.135	0.135
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 15: TRI Sites: Repeat Sales Disaggregated Model

ln(saleprice)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Sites	0.222	0.072	-0.063	-0.014	-0.053**	-0.082***	-0.061***	-0.102***
	(0.203)	(0.073)	(0.043)	(0.033)	(0.025)	(0.020)	(0.014)	(0.011)
Noxious	-0.259***	-0.144***	-0.094***	-0.062***	-0.021**	(0.004)	-0.015**	0.008*
	(0.076)	(0.034)	(0.020)	(0.013)	(0.010)	(0.008)	(0.006)	(0.005)
Carcinogenic	-0.01	-0.167**	-0.05	-0.02	-0.067***	-0.087***	-0.051***	-0.036***
	(0.202)	(0.066)	(0.036)	(0.023)	(0.017)	(0.014)	(0.011)	(0.008)
Industrial	-0.147***	-0.0640***	-0.036***	-0.022***	-0.010***	-0.003*	-0.007***	-0.010***
	(0.019)	(0.007)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
Commercial	0.0193***	0.00871***	0.005***	0.004***	0.003***	0.002***	0.002***	0.001***
	(0.002)	(0.001)	0.000	0.000	0.000	0.000	0.000	0.000
Constant	5.368***	5.244***	5.349***	5.335***	5.348***	5.352***	5.472***	5.670***
	(1.199)	(1.191)	(1.239)	(1.138)	(1.098)	(1.136)	(1.111)	(1.038)
Observations	350331	350331	350331	350331	350331	350331	350331	350331
R-squared	0.134	0.134	0.134	0.135	0.135	0.135	0.135	0.135
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501
Clustered Standard Errors on the parcel level								
Robust standard errors in parentheses								
*** p<0.01, ** p<0.05, * p<0.1								

Table 16: TRI Emissions: Repeat Sales Univariate and Industry Specific Controls

Univariate Repeat Sales

Variable	.5 KM	1 KM	1.5 KM	2 KM	2.5 KM	3 KM	4 KM	5 KM
TRI Emissions	-0.0821**	-0.0880***	-0.0708***	-0.0466***	-0.0467***	-0.0391***	-0.0337***	-0.0246***
	(0.039)	(0.017)	(0.011)	(0.007)	(0.005)	(0.004)	(0.003)	(0.002)
Constant	5.337***	5.356***	5.373***	5.389***	5.455***	5.490***	5.670***	5.768***
	(1.167)	(1.179)	(1.176)	(1.173)	(1.155)	(1.161)	(1.215)	(1.226)
Observations	350331	350331	350331	350331	350331	350331	350331	350331
R-squared	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501

Industry Controls

Variable	.5 KM	1 KM	1.5 KM	2 KM	2.5 KM	3 KM	4 KM	5 KM
TRI Emissions	-0.101**	-0.0820***	-0.064***	-0.038***	-0.037***	-0.034***	-0.029***	-0.017***
	(0.040)	(0.017)	(0.011)	(0.007)	(0.005)	(0.004)	(0.003)	(0.002)
Industrial	-0.143***	-0.0630***	-0.035***	-0.022***	-0.013***	-0.008***	-0.010***	-0.011***
	(0.019)	(0.007)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Commercial	0.0193***	0.00892***	0.006***	0.005***	0.003***	0.003***	0.002***	0.001***
	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	5.371***	5.241***	5.319***	5.327***	5.339***	5.324***	5.509***	5.782***
	(1.199)	(1.195)	(1.229)	(1.133)	(1.080)	(1.084)	(1.116)	(1.053)
Observations	350331	350331	350331	350331	350331	350331	350331	350331
R-squared	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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

Table 17: TRI Emissions: Repeat Sales Disaggregated Model

Ln(price)								
Variable	**.5 KM**	**1 KM**	**1.5 KM**	**2 KM**	**2.5 KM**	**3 KM**	**4 KM**	**5 KM**
TRI Emissions	0.097	0.117***	0.067***	0.066***	0.016	0.047***	0.030***	-0.035***
	(0.113)	(0.042)	(0.025)	(0.019)	(0.015)	(0.013)	(0.009)	(0.007)
Noxious	-0.326**	-0.268***	-0.181***	-0.137***	-0.048**	-0.068***	-0.058***	0.029***
	(0.148)	(0.058)	(0.034)	(0.025)	(0.019)	(0.015)	(0.011)	(0.008)
Carcinogenic	-0.055	-0.246***	-0.120***	-0.079***	-0.084***	-0.125***	-0.075***	-0.004
	(0.236)	(0.072)	(0.039)	(0.027)	(0.020)	(0.016)	(0.013)	(0.010)
Industrial	-0.145***	-0.0641***	-0.037***	-0.023***	-0.011***	-0.004***	-0.008***	-0.010***
	(0.019)	(0.007)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
Commercial	0.0192***	0.00857***	0.005***	0.004***	0.003***	0.003***	0.002***	0.001***
	(0.002)	(0.001)	0.000	0.000	0.000	0.000	0.000	0.000
Constant	5.364***	5.263***	5.327***	5.312***	5.324***	5.278***	5.384***	5.773***
	(1.20)	(1.20)	(1.23)	(1.14)	(1.08)	(1.08)	(1.07)	(1.09)
Observations	350331	350331	350331	350331	350331	350331	350331	350331
R-squared	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14
Number of PIN	118501	118501	118501	118501	118501	118501	118501	118501

Clustered Standard Errors on the parcel level

Robust standard errors in parentheses

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