The Capacity of Hedonic Pricing Analysis to Reflect The Economic Benefits Of Air Quality

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Abstract

This paper examines the impact of a change in the environment on property prices, in a municipality in northern France, from period 2008 to 2011. It aims to shed light simultaneously on the economic benefits of a reduction in pollution, and on people's willingness to pay for perceived differences in environmental attributes. To do this, I apply a hedonic price analysis to the recent closure of the oil refinery in Dunkirk in northern of France, in September 2009, which constitutes a natural experiment. This research shows, that the permanent closure of the plant led to a reduction in the concentration of sulphur dioxide (SO_2). Although the reduction in SO_2 induces an objective and positive effect on health, people's perceptions derived from the hedonic approach, do not always respond positively to the improvement in air quality. The estimates here suggest that the environmental effect is in fact smaller in relative terms for buyers of cheaper properties than the overall economic effect.

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1 Introduction

The decision to live next to a toxic site may be associated with a wide number of concerns. As Portney (1981) suggests, it may be possible to draw inferences about individuals' evaluation of risk, by combining estimates of the effect of air pollution on both property values and human health risks. This paper aims to evaluate the consequences of changes in atmospheric pollution following the closure of a toxic site.

Rosen (1974)'s hedonic model shows that the willingness to pay for a change in natural resources can be inferred by the explicit price of a property. Empirical evidence about the distribution of the benefits of environmental policy based on housing market studies are limited due to methodological challenges. However, Chay and Greenstone (2005) find that the elasticity of house values with respect to the concentration of particulates ranges from -.20 to -.35. Greenstone and Gallagher (2008) look at areas chosen for Superfund-sponsored cleanup programs of hazardous waste sites, compared to their counterparts. They find that Superfund cleanups are associated with economically small and statistically insignificant changes in residential property values, property rental rates, housing supply, total population, and the types of individuals living near the sites. The estimates from Hanna (2007) suggest that being a mile closer to a polluting manufacturing plant reduces house values by 1.9%. Besides, the literature also focuses on the relationship between health and house prices. The Superfund cleanups of hazardous waste sites have also been used to shed light on their impact on health status at birth (Currie et al., 2011). Davis (2004) measures the effects of health risks on house values, by exploiting an isolated county in Nevada where residents have experienced a severe increase in pediatric leukemia. The estimated marginal willingness to pay (MWTP) to avoid pediatric leukemia risk is used to calculate the value of a statistical case of pediatric leukemia. Most recently, Currie et al. (2013) looked at the housing market and health impacts of 1,600 openings and closures of industrial plants that emit toxic pollutants. The paper shows that house values within one mile decrease by 1.5 percent when plants open, and increase by 1.5 percent when plants close.

By using the housing market to estimate the economic benefits of air quality, hedonic pricing analysis (HPA) only captures people's willingness to pay for perceived differences in environmental attributes, and their direct consequences. However, individuals' perception of health risks may differ from the real risk of population which living near toxic sites actually leads to. Bento (2013) states that hedonic princing methods may fail to provide suitable estimates of the WTP for air quality improvements.

In this paper, I compare the monetary evaluation of environmental benefits with people's willingness to pay for perceived differences in environmental attributes, in order to see whether assessments converge. In other words, this study on air pollution and house prices analyzes to what extent HPA captures people's willingness to pay for perceived differences in environmental attributes (perceived health risks from pollution and perceived environmental amenities) and how it may differ from objective and biological environmental health risks.

The analysis focuses on Dunkirk, a French municipality in the Nord-Pas de Calais region, where residents recently experienced a refinery closure, though this has not been the only one in France. Pollution, health outcomes and house prices are compared before and after the closure with the nearby municipalities, within 50 kilometers of Dunkirk. At least one environmental monitoring station is used as a control group.

People living near the refinery may actually be concerned differently by the refinery closure. In fact, in the case of the closure in Dunkirk, there have been both economic and environmental effects. First, the refinery closure produced an economic shock in terms of employment and economic activity in the surroundings of Dunkirk. As the population became unemployed, the economy of the area stagnated. The slowdown in activity decreased the wealth of people living in the vicinity of the refinery. Economic activity can have a direct impact on prices and may bias the estimate. Nevertheless, this economic shock affected the entire Nord-Pas de Calais region in terms of economic outcomes, due to the direct and indirect employment consequences of the refinery's closure.

Second, the environmental shock corresponds to a decrease in the concentration of pollution in the area of Dunkirk, following the closure. Thus, I assume that the closure of the refinery may have reduced health risks from air pollution, and is likely to have increased the aesthetic value of the site's vicinity. Finally, closure may have enhanced the value of neighborhood properties.

I first show that the closure of the refinery led to a reduction in air pollution. Bearing in mind the positive effect of the closure on the aesthetic value of site's vicinity and on health, I show, in parallel, that the effects of the refinery closure on property prices are not always as expected. This evaluation may be of use in testing the hypothesis under which the willingness to pay for a perceived reduction in pollution is in line with the economic benefits of an improvement in the concentration of air pollution.

2 Pollution, Health and Refinery Closure

2.1 SO_2 pollution and health

This paper focuses on sulfur dioxide (SO_2), one of the major pollutants emitted by oil refineries and the main industrial pollutant. Sulfur dioxide (SO_2) is one of a group of highly reactive gasses known as oxides of sulfur (SO_x). The largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities (Environmental Protection Agency (EPA), 2011). SO_2 is a colorless gas with a very strong smell. SO_2 is subject to transformation in the atmosphere and can react with other compounds to form small particles. These particles go deeply to lungs and can cause or aggravate respiratory diseases, such as emphysema and bronchitis.

People exposed to SO_2 showed decreased lung functioning for children and increased respiratory symptoms for adults (World Health Organization (WHO), 2011), asthma crises and ocular rashes (Pierre Lecoq, 2009). Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract (World Health Organization (WHO), 2011). The effects seem stronger for high levels of exposure and people with asthma are more sensitive to SO_2. The number of hospital admissions for cardiopathy and mortality increases on days with a high SO_2 air concentration (Finkelstein et al., 2003). Human clinical studies consistently demonstrate respiratory morbidity among exercising asthmatics following peak exposures (5-10 min) to SO_2 concentrations equaling 0.4 ppm, with respiratory effects occurring at concentrations as low as 0.2 ppm for some asthmatics (World Health Organization (WHO), 2005).

2.2 Pollution and the refinery closure

Refineries are responsible for 20 % of the SO_2 released in France (Soleille, 2004). Oil refineries convert crude oil to everyday products like gasoline, kerosene, liquefied petroleum. Crude oil and coal contain a relatively high quantity of sulfur. SO_2 is created when crude oil or coal is heated at the refinery to produce fuel. The refining process releases a large number of chemicals such as benzene, chromium and sulfur acid into the atmosphere. Therefore, refineries are considered as so-called upper tier SEVESO sites for most of their activities. In Europe, the "Seveso" directive applies to around 10,000 industrial establishments where dangerous substances are used or stored in large quantities, mainly in the chemicals, petrochemicals, storage, and metal refining sectors. The Seveso Directive compels Member States to ensure that operators have a policy in place to prevent major accidents.

The Flandres refinery, close to Dunkirk in northern France, is a SEVESO site. The refinery produces liquefied gases (propane and butane), fuel for airplanes and automobiles (gasoline and diesel), domestic and industrial fuel and biofuels. Its refining capacity is up to 7.8 million tonnes per annum. The refinery employs nearly 370 employees on average, which represents 0.4% of overall employment in Dunkirk. The refinery also annually works with 775 establishments which generate Eur 87 million in turnover, including 275 establishments localated in Nord-Pas de Calais, and which produce Eur 44.1 million in turnover. Most of the employees live near their workplace: two thirds of the employees of the refinery live in Dunkirk. Most of them work full-time, with a permanent employment contract and are manual workers. One quarter of the refinery's employees are in intermediate professions (INSEE, 2010). In September 2009, the production of the refinery was shut down due to poor demand and margins. Given a poor economic outlook, the French oil giant Total announced the definite closure of the refinery in 2010. I reasonably believe that the closure had an impact on all the Nord-Pas de Calais region, affecting not only refinery workers but also a large range of subcontractors throughout the region.

2.3 The incidence of the refinery closure on house prices

A hedonic model The hedonic price model, derived mostly from Lancaster (1966)'s consumer theory and Rosen's (1974) model, assumes that a differentiated good can be described

by a vector of its characteristics. The hedonic approach to evaluation aims at estimating the economic value of a good, using the implicit price of the product's attributes. In the case of a property, these characteristics may include structural attributes (e.g., number of bedrooms), neighborhood public services (e.g., quality local schools), and local environmental amenities (e.g., presence of a toxic site). People have the opportunity to select the combination of features they prefer, given their income. In this context, areas with elevated health risks such as Dunkirk must have lower house prices to attract potential homeowners.
However, valuations derived from hedonic price functions must be interpreted carefully. The literature emphasizes a wide number of criticism of HPAs.

With perfect information, the price differential associated with proximity to hazardous sites reflects both individuals' valuations of the greater health risk as well as any effect on neighborhood aesthetics (Greenstone and Gallagher, 2008). Although a biological health risk may exist, it is not clear to what extent individuals are fully and correctly informed about the health impacts of air pollution. Although individuals may be aware about air pollution, it is less likely that they correctly incorporate this risk into their pricing decisions for housing. Imperfect information suggests that the hedonic approach underestimates the true health cost of air pollution, whereas damage functions may tend to overestimate the health costs as mortality may be too high (Delucchi et al., 2002). Cropper (2000) notes that it is more likely that the property values used in HPAs capture all of the aesthetic costs and benefits, but only a portion of the health costs benefits. Zabel and Kiel (2000) emphasize that it is still unclear how individuals process air quality information when determining their willingness-to-pay for housing.

Another controversial issue is that of market segmentation. E.I. et al. (1996) noted that in theory, hedonic price studies do not require the segmentation of housing markets if all attributes are adequately taken into account. However, in practice, several types of market segmentation are likely to exist in most markets. This is because housing markets are not uniform (Adair et al., 1994),(Fletcher et al., 2000). Hence, it is unrealistic to treat the housing market in any geographical location as a single entity. For instance, houses and flats should be considered separately, due to their specificities and differences in price trends. Unfortunately, the definition, composition, and structure of sub-markets have not been given much attention in the hedonic-price literature, although this is an important empirical issue.

A remaining issue frequently associated with the hedonic price model is pollution endogeneity. HPAs consider that pollution is an exogenous variable in the regression of house prices. This is not always correct. Industrial facilities, which are sources of pollution, are probably located in areas with specific characteristics such as low population and relatively low house prices. On the one hand, employees from an industrial company are willing to live close to their place of work so as to limit everyday transport. On the other hand, atmospheric pollution reduces air quality and the attractiveness of living nearby pollution sources. In this context, property prices should decrease. Bajari et al. (2012) suggest that ignoring bias from time-varying correlated unobservable variables considerably understates the benefits of a pollution reduction policy. In fact, the presence of omitted variables may be correlated with the pollutants. Confounding factors, such as the opening of new businesses, may evolve over time in conjunction with worsening air pollution. It appears that failing to control for omitted attributes or controlling for time-invariant unobserved attributes with fixed effects only leads to the wrong sign on the estimate of the potential benefits of a pollution reduction policy. When differences between locations are imperfectly measured and covary with health risks and house prices, it becomes difficult to disentangle the price effects of health risks from the price effects of other locational amenities (Davis, 2004).

As developed by Chay and Greenstone (2005), differences in terms of pollution preferences may also lead to self-selection bias. Households may sort themselves into locations endowed with amenities that match their preferences. For instance, people with high preferences for air quality may sort themselves into locations with high levels of air quality. The subsample studied may not be representative of the whole population. In this case, the hedonic estimation only reflects the marginal prices of air quality for a part of the population which does not value air pollution. The value of the marginal price of air pollution will be underestimated.

A last issue frequently associated with the hedonic price model is the misspecification of variables. Over-specification (i.e., the inclusion of an irrelevant variable) leads to estimated independent variables that are both unbiased and consistent, but inefficient. In contrast, under-specification results in estimated coefficients that are both biased and inconsistent. According to Butler (1982), since all estimates of hedonic price models are to some extent misspecified, models that use a small number of key variables are generally suitable.

These criticisms underline the need to develop novel methods to improve our ability to estimate the marginal willingness to pay for environmental improvements Bento (2013). To mitigate these problems and to infer the impact of a reduction in air pollution on house prices and health status, I use a quasi-experimental approach. The analysis focuses on Dunkirk, a French municipality in the Nord-Pas de Calais region, which residents have recently experienced a refinery closure. Apart from this, the conditions of supply and demand for housing are relatively similar to the rest of the Nord-Pas de Calais property market, so that I can expect a similar set of implicit prices in Dunkirk and in its surroundings, when analyzing flats and housing separately. People living in Dunkirk may have a high-risk behavior leading to a low health status. The cessation of refining allows the effect of pollution on a population exposed to the emissions from the refinery to be measure well, when compared to populations living far from the refinery and not exposed to its pollution. The use of variations in pollution and health risks over time is of particular interest when controling for unobserved differences across locations. Using a really rich and exhaustive dataset for property transactions, I am also able to shed light on population sorting. Kuminoff et al. (2010) suggest that large gains in accuracy can be realized by moving from the standard linear specifications for the price function to a more flexible framework that would use a combination of spatial fixed effects, quasi-experimental identifications, and temporal controls for housing market adjustment. Taking these elements into account, I analyze the link between the reduction in air pollution, due to Dunkirk refinery's closure, and property values.

The theoretical basis of the evaluation Before going into more detail about the empirical results, in this section, I develop a theoretical model to compare willingness to pay across population/ housing market segments. I adapt a model by Brookshire (1982), and the starting point for theoretical utility analysis concerns households utility maximization problems. A household's utility function is denoted as $U(X; P; \vec{Z})$. X represents a private composite, P is the level of air pollution and $\vec{Z}$ represents the vector of the housing attributes, including the type of property (house or flat). The variable P represents an environmental quality variable, the level of pollution, and is assumed to be a "'public"' bad not chosen by households. It enters the preference structure such that the marginal utility of pollution decreases $\partial u/\partial P < 0$. In contast, the utility is an increasing function of consumption $\partial u/\partial X > 0$.

Each household maximizes utility subject to the full income budget constraint:

$$Y - CX - R(P, \vec{Z}) = 0$$

where Y is the household income, C is the unit cost or the price of the commodity and R is the rent gradient as defined by Rosen. As usual in this literature, I assume a decline in rents when the distance from the polluted site decreases, or equivalently, a decrease in rents when the pollution increases $\partial R/\partial P < 0$. The first order conditions for the choice of P and X implies that:

$$C\frac{U_P}{U_X} = R_P(P, \vec{Z}); C\frac{U_{\vec{Z}}}{U_X} = R_{\vec{Z}}(P, \vec{Z})$$

Thus a hedonic rent gradient is defined for pollution P and different types of property as well.

Let us assume two households A and B with identical preferences but different incomes ($Y^A > Y^B$). As illustrated in Graph 1 1, if the initial level of pollution is given by P_0, household A, located at P_0 , has an indifference curve I^A, while household B has an indifference curve I^B, also located at P_0. Household A, with income Y^A, would then face a rent gradient like that shown in Figure 1 defined by $R(P)$ [1] and chooses point a and household B, with income Y^B, would then face a rent gradient defined by $R(P)$ and chooses point b. Therefore, the graph shows that households with different levels of income, after a change in pollution from P_0 to P_1', may face the same rent gradients over pollution and that their absolute WTP should be equal. Nevertheless, perceptions about the level of pollution can be misjudged. If a poorly informed household underestimates the change in pollution from P_0 to P_1' due to

[1] Since it is assumed that the households share the same preferences, there is no reason for them to choose different housing attributes for a given level of pollution. For this reason, $\vec{Z}$ is omitted here.

a lack of awareness, the rent differential of the well-informed household will exceed the rent differential of the poorly informed household. The graph is drawn under the assumption that income and information (or the ability to use information) are correlated because of the usual evidence about the link between education and income. But this informational failure could have different consequences, and the final effect on the difference between the rent differentials that affect both households is ambiguous. The poorly informed household could underestimate the initial level of pollution P_0, or underestimate and also overestimate the difference P_0 - P_1. It is thus clear that such an informational failure introduces some noise in the differential rent measures which may explain some discrepancies between classes of households. As shown by Brookshire (1982), the graph again emphasizes that the rent differential always underestimates the WTP of each type of households. Moreover, in case of imperfect information about the real level of pollution (or its health effects), even the absolute willingness to pay may differ. Thus, information plays an important role in the perception of pollution and may lead to different rent gradients.

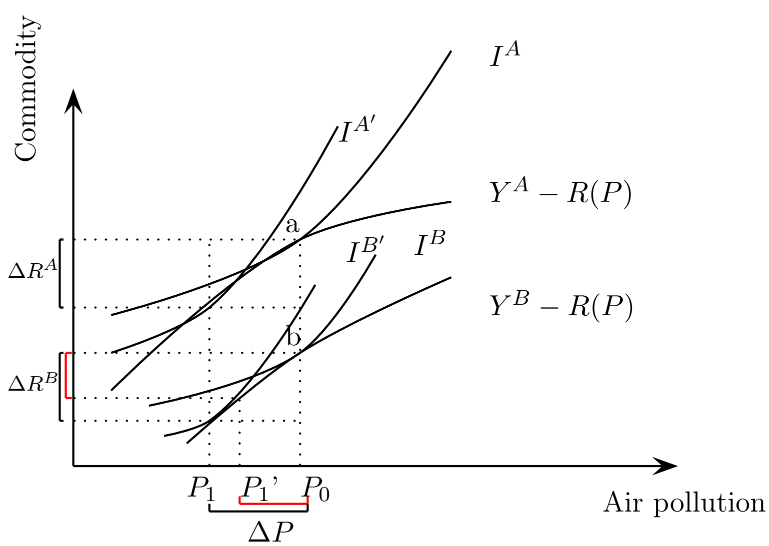

Figure 1: The evolution of Rent with a Lack of Information

Let us now observe what happens if we consider different preferences for agents, allowing different market segments, such different price categories to be distinguished. As illustrated in the Graph 2, household A, located at P_0, with an indifference curve I^A, buys an expensive property $\vec{Z}^A$ while household B, with an indifference curve I^B, also located atP_0 buys a cheap property $\vec{Z}^B$. Household A, with income Y^A, would then face a rent gradient like that shown in Figure 2 defined by $R(P, \vec{Z}^A)$ and chooses point a. In contrast, household B, with income Y^B, would then face a rent gradient defined by $R(P, \vec{Z}^B)$ and chooses point b. Therefore, households with different type of property, after a change in pollution from P_0 to P_1, may face different rent gradients over pollution, as emphasized in the Graph 4.2. The change in the rent gradient of an expensive dwelling ΔR^A exceeds the change in the rent gradient of a cheap property ΔR^B. Thus, people living near the refinery in a cheap or an expensive property may actually be concerned differently by the refinery's closure.

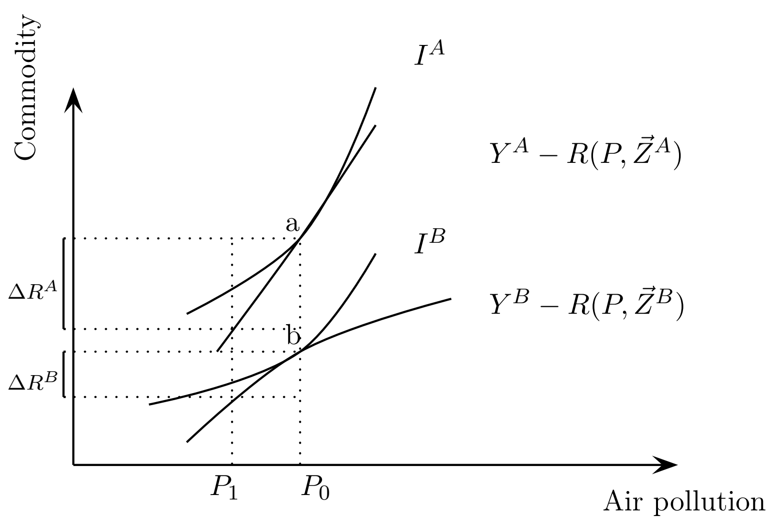

Figure 2: The Evolution of Rent with Respect to Market Segments

If we want to address the role of different spending constraints, let us assume that each household has the same minimal level X_0 of commodity consumption (to satisfy the primary needs of households besides accommodation such as energy, water or minimal food consumption).

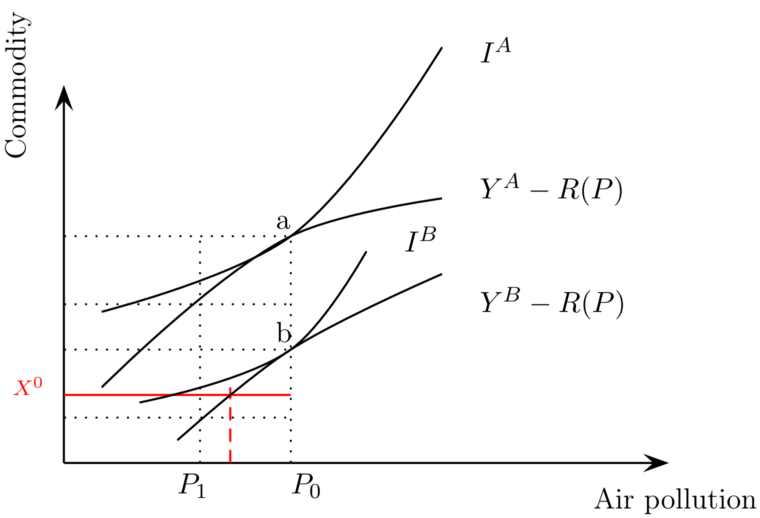

Figure 3: The Role of Different Spending Constraints

In this case, with X_0 be binding, the households cannot freely maximize their utility and have to "choose" a level of rent corresponding to a higher level of pollution than the real level (Graph 4.3). Their WTP is constrained by their budget constraint.

3 A presentation of the Dataset

3.1 Pollution data

Air quality is monitored throughout France (mainland and overseas départements) by 38 approved air quality monitoring associations (AASQA). The French monitoring station system includes approximately 700 measurement stations equipped with automatic instruments and nearly 400 experts operating this monitoring system. I focus on the concentration of sulfur dioxide (SO_2) in the Nord-Pas de Calais region, in a radius of 50 kilometers. This represents two départements: i.e, the administrative and geographical level below France's region, and roughly similar to counties in the United Kingdom or the United States. The data used here includes daily measures of ambient air pollution concentrations in micrograms per cubic meter ($\mu g/m^3$) from all air quality monitors in France for 2008-2011, provided by the Ministry for Ecology, Sustainable Development and Spatial Planning (ADEME) database and more recent data from the National Institute of the Industrial Environment and Risks (INERIS).

Table 1 presents the summary statistics of all the variables. Monthly pollution concentration data are presented in panel A of the summary statistics, which also provides a measure of expected exposure to SO_2 after having dropped stations that did not exist during the entire period, from 2008 to 2011. In addition, monitoring stations that do not measure SO_2 have also been removed. It should also be noted also that only some municipalities dispose of a monitor. The 2 departments represent 238 municipalities and 16 air pollution monitoring stations.[2] The distribution of monitoring stations throughout France is represented in Figure 4 with a marker which represents the area of the study, 50 kilometers around Dunkirk, in the Nord-Pas de Calais.

[2] There is still a difference in observations because I face some missing data.

Table 1: Summary Statistics Mean[SE]

Variables	The entire period	Before Sept. 2009	After Sept. 2009
	Panel A : Pollution concentration N=185,687		
Sulfur dioxyde(SO_2) ($\mu g/m^3$) mean	2.120748[1.787319]	2.478793 [1.995779]	1.485385[1.078837]
	Panel B : Weather variables		
Precipitation (mm)	2.008765 [1.015537]	2.087354 [.8599679]	1.869306 [1.232342]
Max_Temp (^0C)	14.59093 [6.513577]	14.25712 [6.044898]	15.18327 [7.233453]
Av_Temp (^0C)	10.73392 [5.627273]	10.4839 [5.27849]	11.17759 [6.173196]
wind_speed (m/sec)	7.827492 [1.123382]	7.956915 [1.17471]	7.597826 [.9849877]
Wind_direct (rose des vents)	206.6803 [44.91593]	211.3447 [40.79121]	198.4032 [50.37515]
Min_Humidity (%)	60.00654 [11.78418]	60.55584 [10.71448]	59.0318 [13.41971]
Max_Humidity(%)	93.76189 [2.770849]	92.83191 [2.65916]	95.41219 [2.120282]
	Panel C : socio-economic variables		
Age (in days)	13389.47 [12241.85]	13389.47 [12241.86]	13389.47 [12241.86]
Unemployment (%)	12.2314 [2.432976]	11.5939 [2.346794]	13.01057 [2.3063]
	The entire period	Before 2010	After 2010
	Panel D : Property variables N=16718		
price_ttc (euros)	148634.8 93419.96	146228.1 67929.61	150890.8 112130.4
attic (dummy)	.1183156 .3229911	.1199159 .3248833	.1168154 .3212188
balcony (dummy)	.0401962 .196425	.0374583 .1898937	.0427628 .2023336
parking (dummy)	.3385788 3.57314	.3825969 3.583482	.2958153 3.562757
house_srf (m^2)	97.14408 44.0163	96.83583 41.95927	97.42974 45.84205
less_5_years (dummy)	.093492 .2911294	.1016195 .3021659	.0858732 .280193
room_nb (number)	3.668182 2.328882	3.781308 2.243965	3.562123 2.401067

Note: This table indicates the mean and standard error for the estimation of key variables from 2008 to 2011 in France, before the shutting down of the refining process and after formal closure of the refinery, in the north of France. There are 13,870 houses and 2,848 flats in the dataset.

The summary statistics indicates that the monthly SO_2 concentration decreased after the refinery closure. The level was quite low over the period due to the monthly aggregation of daily data. The concentration of Sulfur dioxide after the refinery closure in Dunkirk decreased from 12.65 to 6.58 $\mu g/m^3$ whereas SO_2 concentration in the other municipalities, decreased from 3.12 to 2.21 $\mu g/m^3$ on average. As a result, the difference-in-differences between Dunkirk and the control group after the refinery closure is 5.16 $\mu g/m^3$. I have also performed an independent samples t-test to compare the means of a normally-distributed interval-dependent variable for two independent groups. The results indicate that there is a statistically significant difference between concentration of SO_2 for the control group and Dunkirk (p = .000). In other words, Dunkirk has a statistically significantly higher SO_2 concentration (9.920242) than the control group (2.725086).

Figure 4: Monitoring Stations and the Nord-Pas de Calais Region

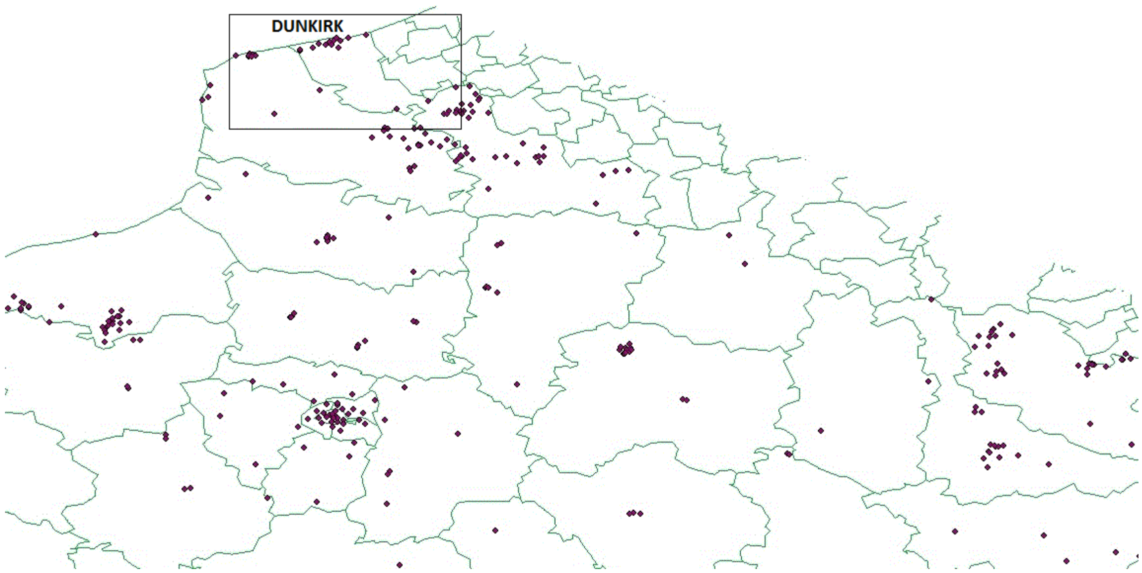

Figure 5: *

Note: This figure represents the distribution of monitoring stations in France. The marker sheds light on the area of the study.

3.2 Weather data and socioeconomic data

Temperature, precipitation, humidity and wind data are used in the analysis to control for both the direct effects of weather on health (Chay and Greenstone, 2003) and also to leverage the quasi-experimental features of wind direction and wind speed in distributing pollution from refineries (Hanna and Oliva, 2011), (Beatty and Shimshack, 2011). The weather data comes from Meteo France, the French national meteorological service, and includes: the average and maximum temperature in degrees Celsius; the level of precipitation in millimeters; the maximum wind speed in meters per second; the prevailing wind direction in wind rose and the maximum and minimum relative humidity in percent.[3] The data is supplied daily by the French weather monitoring system. Measures from one nearby station per department are used as a control in the regression. Weather data are presented in Panel C of the summary statistics.

[3]The relative humidity of an air-water mixture is defined as the ratio of the partial pressure of water vapor in the mixture to the saturated vapor pressure of water at a prescribed temperature.

Temperature and the intensity of sunlight play an important influence in the chemical reactions that occur in the atmosphere to form photochemical smog from other pollutants. Also, wind speed and direction measurements are important for air quality monitoring. If high pollutant concentrations are measured at a monitoring station, the wind data recorded at the station can be used to determine the general direction and area of the emissions. Wind speed can greatly affect the pollutant concentration in a local area. The higher the wind speed, the lower the pollutant concentration. Wind dilutes pollutants and rapidly disperses them throughout the immediate area. Humidity and precipitation can also act on pollutants in the air to create more dangerous secondary pollutants, such as the substances responsible for acid rain. In contrast, precipitation have a beneficial effect by washing pollutant particles from the air and helping to minimize particulate matter formed by activities such as construction and some industrial processes (Environmental Protection Agency (EPA), 2012a).

The quarterly rate of unemployment is taken from the National Institute of Statistics and Economic Studies (INSEE).

3.3 Property Prices

A unique and detailed dataset -PERVAL- compiled by the Chambre of Notaires(who records property transactions) is used to provide property prices. It gives information of every property transaction in a radius of 50 km around Dunkirk from 2008 to 2011. The geographic region for the control group is then represented by all towns with centers within 50 km of the refinery in Dunkirk. The control variables that are used in the estimation have very few missing values for the dataset to be as exhaustive as possible. Panels E and F of Table 1 present the main characteristics of the property transactions: respectively 2,848 and 13,870 for flats and houses. The key variables are the property prices, the number of floors, the number of rooms, the type of flat or house, the property surface, the presence of a terrace, an attic, a parking space, a balcony, a pool or a garden and a variable which indicates if the property is less than 5 years old. The summary statistics show that average property prices for both houses and flats increased after the refinery closure, while 30% of flats in the region were less than 5 years old during the period of study. This latter point is important, because in December 2008, the so-called "Scellier" Law was passed. It gave significant income tax breaks (25% to 37% spread over 9 to 15 years) to taxpayers who bought new housing units (new or in completion) between January 1, 2009 and December 31, 2012. The goal of the law was to boost rental properties and increase the attractiveness of investment in new construction with much higher environmental standards.

4 The Estimation

The aim here is to examine the causal relationship between the closure of a refinery, local pollution levels, and the property prices in the north of France.

The purpose, first, is to estimate the impact of the refinery closure $post\_closure_{cm}$ on the concentration of pollution Y_{cm} captured by the parameter β_1 in the following linear probability model:

$$Y_{cm} = \beta_0 + \beta_1 post\_closure_{cm} + \beta_2 post_{cm} + \beta_3 closure_{cm} + X_{cm} + \theta_m + \omega_y + \epsilon_{cm} \quad (1)$$

where the dependent variable Y_{cm} represents SO_2 pollution concentration within each municipality c at month m according to the model presented. The variable $post_{cm}$ represents the time span after the refinery closure in September 2009. All regressions also include the variable $closure_{cm}$, coded as 1 for Dunkirk, to control for time-invariant unobserved covariates of respiratory admissions. The control group coded as zero represents the remaining municipalities in the north of France with at least one monitoring station. The variable $post\_closure_{cm}$ is the difference-in-differences estimator and represents the Dunkirk area following the refinery closure in 2009. As only monthly hospital admissions data is available, the daily concentration of pollution measures are also aggregated here on a monthly basis. [4] X_{cm} is a vector of municipality controls that includes weather controls W_{cm}. Time variations in pollution are also controlled for - including month fixed effects θ_m, year fixed effects ω_y to limit the influence of pollution outliers. Finally, ϵ_{cm} represents the error term. This difference-in-differences model assumes the following equation for the model to be valid:

$$\mathbb{E}[\epsilon_{cm}, post\_closure_{cm}] = 0 \tag{2}$$

The refinery in Dunkirk ceased its activity in September 2009, and in October 2010, the owner, Total, announced that the facility would be permanently closed. From a pollution standpoint, emissions ceased in September 2009, and accordingly a monthly model is used when estimating the impact of pollution concentration on health. The chemical life of SO_2 is around 2 days, well below the period of time of the study (a month), which therefore removes any problems of persistence or autocorrelation. If the length of exposure were responsible of a pathology, it would perhaps be possible to identify a change in the population composition instead of the effect of the refinery closure. In fact, employees from the refinery who were very exposed to pollution could leave the Dunkirk area following the plant closure, and this would lead to a reduction in the number of hospital admissions without any effect on health. However, the impact of SO_2 is relatively local, with a direct effect on health so that

[4] When aggregating daily data, the monthly average concentration takes into account monitors without missing data

the concentration from month m does not depend on concentration in the previous month m-1. The exogenous reduction in SO_2 in Dunkirk is responsible for the change which can be observed in the number or the severity of admissions. The effect of refinery closure is well identified.

Similarly, the second objective is to estimate the impact of the refinery closure $post\_closure_{pcy}$ on house prices P_{pcy} or the parameter α_1 in the following linear probability model:

$$P_{pcy} = \alpha_0 + \alpha_1 post\_closure_{pcy} + \alpha_2 post_{pcy} + \alpha_3 closure_{pcy} + W_{pcy} + \varphi_y + \nu_c + \sigma_{cy} \quad (3)$$

where the dependent variable P_{pcy} represents the log price of each property p, within each municipality c at year y. The variable $post\_closure_{pcy}$ represents Dunkirk after the refinery closure in 2009. A semi-log functional form is has been selected here because it fits the data particularly well (Palmquist, 1984). W_{pcy} is a vector of the property and municipalities control values, and includes property characteristics and the level of unemployment in each area. I also control for variations in pollution over time, including a year fixed effect φ_y, in order to limit the influence of pollution outliers. All regressions include a municipality fixed effectν_c, to control for unobserved covariates of prices which are time-invariant. In fact, many of the variations may be explained by unobserved factors that characterize particular properties, such as geographical features, neighborhood characteristics and design amenities (Davis, 2004). σ_{cy} represents the error term.

One of the fundamental assumptions of the hedonic price method, as underlined previously, is that households have perfect information. If people are not fully informed of the linkages between the environmental attributes and benefits to them or their property, then the full value of their homes will not be reflected in house prices. Moreover, the hedonic price schedule does not adjust instantaneously to changes in demand or supply conditions in the housing market. Many factors like imperfect information and transaction costs will then result in the process of adjustment taking some time. In addition, the possibility that the refinery might be definitely closed was evident for some time, due to several court rulings at the beginning of 2010. Before October 2010, people might indeed have suspected that the temporary shut-down would be permanent after September 2009. All buying decisions made throughout the year are therefore included in the model, so that changes in house prices from 2010 may be observed three months after the refinery stopped working, and ten months before its official closure. In other words, the model compares 2010 and 2011, versus 2008 and 2009. It is assumed that 2010 takes into account the delay for adjustment to changes in demand, as well as the expectations of closure people may have held before the refinery was definitely shut down.

Furthermore, the issue of sorting is crucial in this study. Individuals that choose to live near toxic sites may have a low willingness to pay to avoid associated health risks. If consumers value the closure of the refinery, then the closure should cause individuals to sort themselves in such a way that there is an increase in the number of people placing a high value on environmental quality living near the refinery. Hanna and Oliva (2011)'s paper supports the idea that closure may have altered the attractiveness of surrounding neighborhoods for individuals with strong preferences for air quality. If wealthier or healthier people moved closer to the refinery after it has closed, then the estimates might simply be capturing the differences in terms of population characteristics between the old and new residents of the refinery neighborhood. Although focusing on the years around the closure reduces the probability of selective migration, the change in population after closure is also analyzed.

5 Results

5.1 The concentration of pollution and refinery closure

Looking first at the effect of refinery closure on air pollution, the results are interesting in themselves in understanding to what extent refining activity influences the amount of pollution released into the air. Figure 4.5 provides a monthly graph of SO_2 as a residual estimation in $\mu g/m^3$ from 2008 to 2011, for Dunkirk and municipalities far from Dunkirk. The sample is restricted to the Nord-Pas de Calais region. Seasonal patterns are controlled for, adding year and month dummies to deal with the falling pollution trend and the high variation in air pollution observed over time. After closure of the refinery, SO_2 pollution falls in Dunkirk relative to counterpart municipalities where pollution seems to be stable. After closure, the level of pollution concentration in Dunkirk falls to the levels of pollution observed in other municipalities.

Table 2 details this effect more precisely. It presents the estimate of β_1 from Equation (1), in which the *post_closure* variable is replaced by a dummy variable depending on whether or not the municipality is Dunkirk after September 2009. A simple measure of SO_2 in micrograms per cubic meter is given in column 1. Column 2 adds weather control, and column 3 repeats the estimation with municipalities' fixed effects. Column 4 adds the unemployment variable as a proxy for the economic activity trend. In the last column, full advantage is taken of the variation in distance between the municipality and the monitoring station, by reducing the dataset to two kilometers distance between the centroid of the municipality and monitors, in order to have a more precise measure of populations' exposure to air pollution. It should be noted that all specifications include the month, year and municipality fixed effects and are clustered by municipality and month.

Dunkirk, the municipality in which the refinery is located, shows an average reduction

Table 2: First stage regression

VARIABLES	(1) SO_2	(2) SO_2	(3) SO_2	(4) SO_2	(5) SO_2
post_closure	-5.166**	-5.163**	-4.951**	-4.993**	-5.072**
	(2.146)	(2.150)	(2.166)	(2.188)	(2.214)
post	0.856	1.059			
	(0.627)	(0.643)			
closure	9.547***	9.536***			
	(2.065)	(2.060)			
av_temp		-0.764	-0.358	-0.316	-0.221
		(0.431)	(0.439)	(0.447)	(0.462)
pp		-0.192	-0.179	-0.199	-0.243
		(0.156)	(0.156)	(0.163)	(0.164)
max_temp		0.734	0.365	0.348	0.283
		(0.417)	(0.415)	(0.420)	(0.432)
speed_wind		0.362**	0.321*	0.339**	0.405**
		(0.129)	(0.149)	(0.152)	(0.158)
direct_wind		-0.00301	-0.00306	-0.00324	-0.00395
		(0.00473)	(0.00518)	(0.00521)	(0.00540)
min_humidity		0.00528	-0.0242	-0.0209	-0.0252
		(0.0411)	(0.0414)	(0.0409)	(0.0383)
max_humidity		0.0214	0.0306	0.0461	0.0654
		(0.0886)	(0.0948)	(0.102)	(0.101)
Un				-0.327	-0.317
				(0.251)	(0.253)
Year FE	x	x	x	x	x
Month FE	x	x	x	x	x
municipalities FE			x	x	x
Distance < 2km					x
Observations	185,687	185,687	185,687	185,687	175,212
Adjusted R-squared	0.478	0.486	0.503	0.504	0.504

Note: This table presents the coefficient estimates of the reduced form estimate of the effect of the refinery's closure on the concentration of SO_2. All regressions are estimated using OLS, with standard errors clustered at the month and department level. Robust standard errors in parentheses. Statistical significance is denoted by: *** p<0.01, ** p<0.05, * p<0.1

Figure 6: Monthly residual regression for SO_2 in ($\mu g/m^3$) from 2006 to 2011

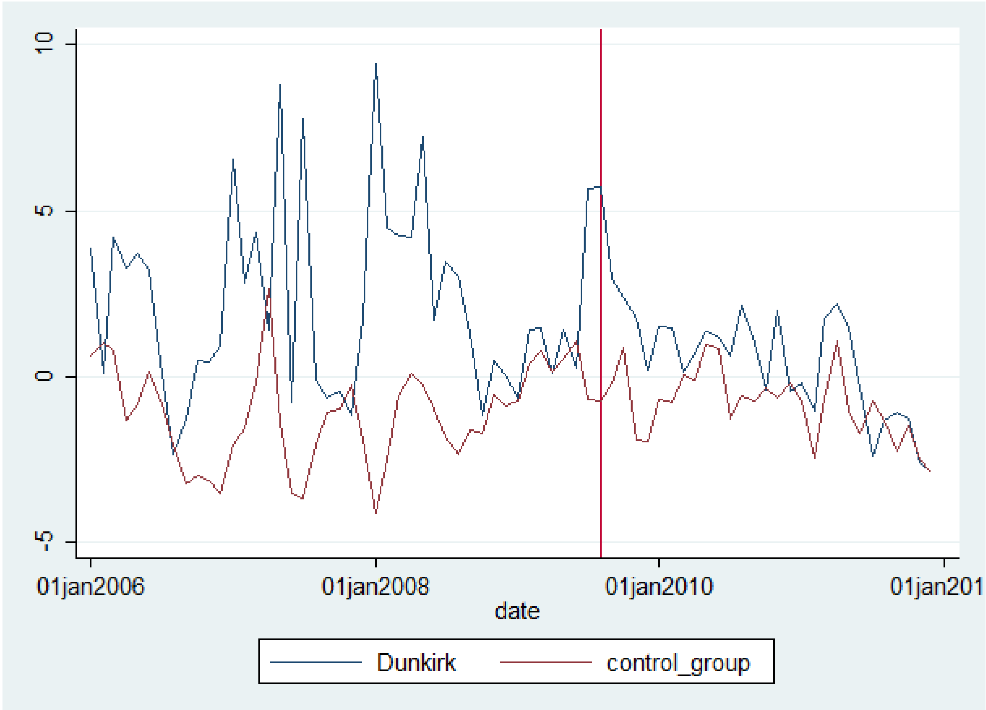

Figure 7: *

Note: This graph represents the SO_2 residual concentration for municipalities with a refinery versus municipalities without a refinery within the same département. September 2009 corresponds to the closure of the refinery.

of 5 micrograms per cubic meter SO_2 in air pollution, after the refinery closed. The closure substantially reduced pollution and it is consistent with all measures of pollution. The estimate is not driven by standard demographic characteristics (column 3), nor by neighborhood specific trends (municipality FE). Taking distance into account increases the magnitude of the effect and the estimate remains significant at the five percent level.

5.2 Property prices and refinery closure

I have previously underlined a causal effect between the closure of the refinery and a reduction in the concentration of pollution. This section looks at how people perceive this reduction in the concentration of SO_2. The refinery closure induces lower health risk (Lavaine and Neidell, 2013) and an aesthetic improvement of the neighborhood. This reduction in pollution and health risk after the refinery closure may also have some effect on property values, reflecting perception and WTP, which are investigated here. An overall property market model is first presented. Then, the dataset is divided in two separated segments due to their specificity and differences in price evolution: flats and houses. Buying a flat is not the same investment decision as buying a house, and the reasons behind such an investment may differ.

Overall property market In these following property models, the exclusion restriction may be violated if other events happen at the same time as the closure. Nevertheless, it is unlikely that this is the case. As far as I know, no other economic events or policies occurred within this particular period. However, the Dunkirk area has been exposed to significant economic downturn. Economic activity is evolving constantly in Dunkirk mainly due to its port, which is France's third largest. Dunkirk is well known as a port handling heavy bulk cargoes for its numerous industrial plants. Dunkirk is also France's leading port for ore and coal imports; France's leading port for containerized fruit imports; France's leading port for copper imports; and the France's second-ranking port for trade with Great Britain. The port's territory covers 7,000 hectares and includes ten towns: Dunkirk, Saint-Pol-sur-Mer, Fort-Mardyck, Grande-Synthe, Mardyck, Loon-Plage, Gravelines, Craywick, Saint-Georges-sur-l'Aa and Bourbourg. According, I use unemployment as a control variable for economic activity in every estimation. Table 3 shows the refinery's closure did not have any impact on unemployment at a census-tract level, because the coefficient is not significant. After the closure, jobs were indeed offered to the workers of the refinery in other plants or units of the Total group. Table 3 also introduces *buyer_migration*, *single* and *male* outcome variables which are coded as one, if housing buyers migrate outside Dunkirk, are single and male respectively. The refinery closure does not have any impact on the composition of the population, as these coefficients were not found to be significant.

Table 3: Other effect for the overall sample

VARIABLES	(1) Migration_buyer	(2) Unemployment	(3) Male	(4) Single
post_closure	-0.0197	0.0317	-0.00468	-0.000505
	(0.0277)	(0.125)	(0.0182)	(0.0315)
Year FE	x	x	x	x
municipality FE	x	x	x	x
Observations	16,718	16,159	16,718	16,718
Adjusted R-squared	0.113	0.964	0.169	0.054

Note: This table presents the coefficient estimates of the reduced form estimate of the effect of the refinery's closure on demographics. All regressions are estimated using OLS, with standard errors clustered at the year and department level. Robust standard errors are in parentheses. Statistical significance is denoted by:*** p<0.01, ** p<0.05, * p<0.1

To reinforce the assumption of homogeneity between the treated and the control group, it is necessary to stress that one municipality in the control group includes the port of Calais. Located on the busiest straits in the world for international shipping, the port of Calais alone handles 1/3 of the traffic between continental Europe and the United Kingdom. In this context, Calais and Dunkirk represent two significant commercial ports in France. As part of the control group, Calais strengthens the existence of a similarity between the treated group and the control group. In addition, Figure 8 shows a similar evolution of unemployment between the control group and the treated group over the period, and provides indications of underlying economic trends. [5] The unemployment time series increases over the period and serves as a time trend in the analysis. The estimation from the hedonic model suggests the proportion of the total variance that is attributed to unemployment only accounts for 0.66%. This is not surprising, given that there are only 370 workers at the refinery and that those 370 workers were offered jobs in other plants or units of the Total group, following

[5] Unemployment is only reported at the quarterly aggregate levels (INSEE) rather than the monthly level for accuracy reasons.

the refinery's closure.

Figure 8: The Evolution of Unemployment from 2008 to 2011

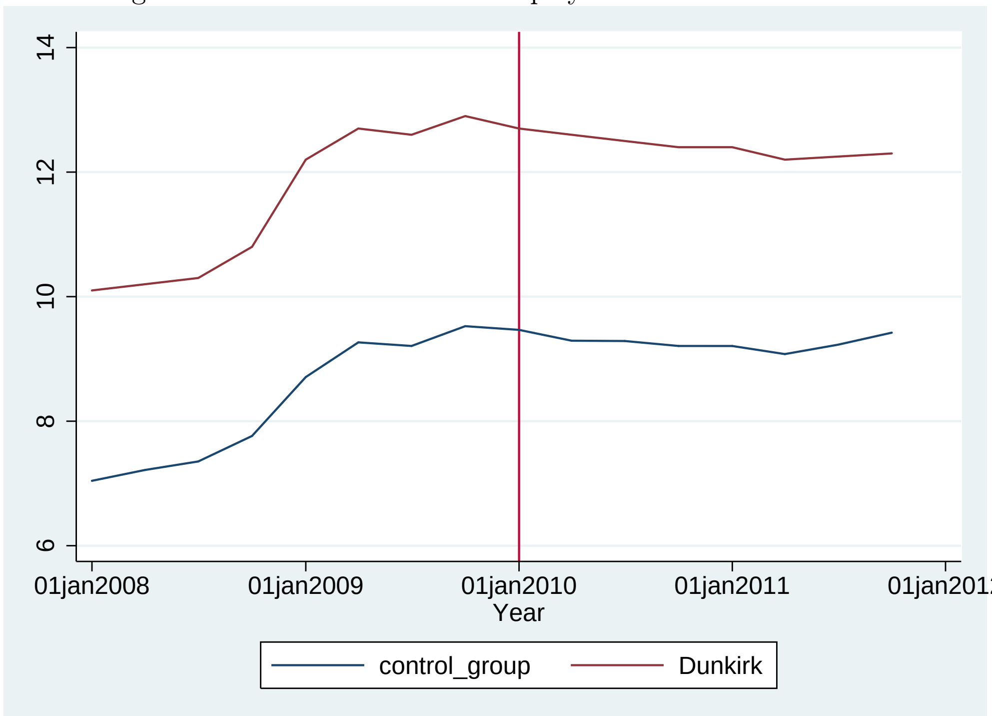

Figure 9: *

Note: This graph represents the quarterly evolution of Unemployment for the area of Dunkirk versus municipalities without a refinery, within a radius of 50 kilometers of Dunkirk. September 2009 corresponds to the refinery closure.

As Currie et al. (2013), in the empirical application here all residents near or far from the refinery live in the Nord-Pas de Calais region, and I assume that the wage effects are similar for both nearby residents and those a little further from a plant. In this context, keeping all other factors fixed, the entire change in property prices following the shock in Dunkirk compared to its counterparts indicates to what extent individuals evaluate health risks and any aesthetics effects on the neighborhood. First of all, Table 4 presents the effect of the refinery closure on the overall property market. While the first block of Table 4 looks at the entire dataset, the second block reduces the sample to municipalities located within a distance of 10 kilometers around the refinery to a more homogeneous dataset in terms of trends (Currie et al., 2013).

Table 4: Reduced form regressions: the overall property market

VARIABLES	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) distance<10km OLS	(6) OLS	(7) FE	(8) FE
post_closure	-0.0637	-0.0143	-0.0169	-0.0199*	-0.0149	0.0409	0.0387	0.0123*
	(0.0586)	(0.0463)	(0.0125)	(0.0104)	(0.0126)	(0.0181)	(0.0190)	(0.00503)
post	0.0661	0.0279			-0.0392**	-0.0346**		
	(0.0708)	(0.0600)			(0.00673)	(0.00788)		
closure	0.0802*	0.102**			0.0238	0.0770***		
	(0.0408)	(0.0305)			(0.0101)	(0.00672)		
terrace		0.121***	0.105***	0.106***		0.0930**	0.0905**	0.0944**
		(0.0208)	(0.0213)	(0.0207)		(0.0227)	(0.0255)	(0.0256)
attic		-0.0574***	-0.0255**	-0.0285**		-0.0169	-0.0173	-0.0282
		(0.0150)	(0.00923)	(0.00874)		(0.0273)	(0.0320)	(0.0244)
balcony		0.189***	0.132***	0.133***		0.0584**	0.0616***	0.0724**
		(0.0234)	(0.0194)	(0.0184)		(0.0122)	(0.01000)	(0.0156)
parking_srf		-7.50e-05	-0.000604	-0.000812		0.00138	0.00256	0.000300
		(0.000850)	(0.00102)	(0.000968)		(0.00104)	(0.00142)	(0.000403)
garden		-0.0173	-0.0588	-0.0566		-0.0226	-0.0206	-0.00586
		(0.0393)	(0.0478)	(0.0486)		(0.0500)	(0.0522)	(0.0500)
house_srf		0.00538***	0.00527***	0.00572***		0.00485**	0.00474**	0.00677***
		(0.000384)	(0.000369)	(0.000185)		(0.00131)	(0.00114)	(0.000241)
less_5_years		0.389***	0.379***	0.382***		0.437***	0.427***	0.441***
		(0.0284)	(0.0405)	(0.0396)		(0.0244)	(0.0273)	(0.0260)
room_nb		0.0423***	0.0436***	0.0374***		0.0726**	0.0709**	0.0455***
		(0.00722)	(0.00790)	(0.00578)		(0.0160)	(0.0130)	(0.00529)
Un				-0.0294				-0.0600
				(0.0205)				(0.0320)
Year FE	x	x	x	x	x	x	x	x
municipality FE			x	x			x	x
distance<10km					x	x	x	x
Observations	16,718	10,957	10,957	10,671	4,335	2,446	2,446	2,160
Adjusted R-squared	0.003	0.401	0.490	0.502	0.003	0.468	0.504	0.562

Note: this table presents the coefficient estimates of the reduced form estimate of the effect of the refinery's closure on the log price of housing. All regressions are estimated using OLS, with standard errors clustered at the year and department level. Statistical significance is denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Column 1 uses a difference-in-differences model without property characteristics. Column 2 adds property characteristics and column 3 controls for municipality specificities using a municipality fixed effect. The last column takes full advantage of the unemployment variable in each municipality to control for any differences in the activity trend between the treatment and control group. Table 4 shows a slight decrease in the price of properties after the closure only when taking unemployment into account. But, this decrease is not robust in all fixed effect models, even when using a more homogeneous dataset in the second block, which reduces distance. Most of the research underlined previously relies on data at some level of aggregation. However, marginal WTP may increase with income. I consider property prices as a proxy for income heterogeneity among households. Price changes may differ across property prices, and when considering all ranges of property prices simultaneously this may strongly bias the estimates. In addition, the heterogeneity of the treatment results is tested by splitting the sample into different price levels.

Table 5: Reduced Form Regressions: Property Prices with Respect to Prices

VARIABLES	(1) price<mean	(2) FE	(3) price>mean	(4) FE	(5) price>75% percentiles	(6) FE	(7) price>90% percentiles	(8) FE
post_treatment	-0.000767	-0.00293	0.0171***	0.0134**	0.0413***	0.0392***	0.0679***	0.0702***
	(0.0152)	(0.0124)	(0.00477)	(0.00459)	(0.00940)	(0.0108)	(0.0170)	(0.0192)
Un		-0.0332*		-0.0144*		-0.00670		-0.0240
		(0.0152)		(0.00735)		(0.00697)		(0.0189)
attic	0.0345***	0.0333***	-0.0147	-0.0173**	-0.0154	-0.0160	0.00543	0.00495
	(0.00792)	(0.00733)	(0.00815)	(0.00656)	(0.00970)	(0.00972)	(0.0112)	(0.0113)
balcony	0.123***	0.119***	0.0361*	0.0401**	0.00639	0.00743	0.00947	0.00933
	(0.0221)	(0.0241)	(0.0160)	(0.0147)	(0.0205)	(0.0198)	(0.0432)	(0.0439)
srf_parking	0.00217**	0.00197**	-0.00383***	-0.00390***	0.000412	0.000416	0.00356	0.00357
	(0.000729)	(0.000720)	(0.000405)	(0.000490)	(0.00411)	(0.00411)	(0.00311)	(0.00305)
srf_hab_init	0.00392***	0.00388***	0.00274***	0.00318***	0.00215***	0.00224***	0.00186***	0.00186***
	(0.000293)	(0.000277)	(0.000360)	(0.000165)	(0.000177)	(0.000135)	(0.000170)	(0.000168)
less_5_years	0.317***	0.320***	0.119***	0.125***	0.0501**	0.0517**	0.0324	0.0330
	(0.0388)	(0.0400)	(0.0115)	(0.0102)	(0.0164)	(0.0168)	(0.0221)	(0.0219)
nbr_pieces	0.0487***	0.0493***	0.00932	0.00406	0.00699*	0.00583	-0.000992	-0.00125
	(0.00344)	(0.00333)	(0.00610)	(0.00437)	(0.00350)	(0.00330)	(0.00402)	(0.00391)
Year FE	x	x	x	x	x	x	x	x
municipality FE	x	x	x	x	x	x	x	x
Observations	5,488	5,289	5,425	5,338	2,679	2,665	1,025	1,023
R-squared	0.310	0.313	0.375	0.395	0.356	0.359	0.414	0.415

Note: This table presents the coefficient estimates of the reduced form estimate of the effect of the refinery's closure on the log price of property by level of property prices. Robust standard errors in parentheses. Statistical significance is denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In Table 5, prices are set below and above the median of property prices, in the first fourth columns. The median house prices is set at Eur 138,000 in the dataset. The estimates are negative but not significant for the subsample below the median of property prices. However, estimates are positive and significant for the subsample above the median of property prices. I also create a subsample of expensive dwellings set above the 75% percentiles, at Eur 179,200 and above the 90% percentiles at Eur 230,000. The difference-in-difference estimator is again positive and significant when considering subsamples above the 75% and 90% percentiles. The higher the price of a property is, the higher the size of the impact.

After the refinery's closure, property prices above the 90% percentile increased significantly, by 7% on average.

While the refinery closure has a positive and significant impact on pollution, results from the hedonic price analysis do not always reflect economic benefits of an improvement in air quality. The results vary substantially with respect to the segment of prices being considered. They first show a lack of significance when the hedonic approach is applied to the overall property market. Prices of expensive dwellings increase after the refinery's closure, and are in line with the environmental-economic intuition. In contrast, there is an absence of results for cheap dwellings. Previous results show that there were no changes in the job market and in the demographic composition of the studied area. This raises clear questions about why I did not find any significant results for the prices of cheap dwellings, even though health and air quality improvments were clearly observed in the Dunkirk vicinity.

Table 6 shows the distribution of property prices by social category. The first block of this descriptive table indicates that more than 60% of factory workers bought property below the median of price in Dunkirk, whereas less than 30% of company managers bought cheap property. However, the second block shows that most executives bought property above the median price, whereas most factory workers bought property below the median. Thus, the prevalence of factory workers - the main social category working in an oil refinery - may explain the absence of results mentioned above for properties below the median price. The results from an independent samples t-test indicate that there is a statistically significant difference between property prices and social classes ($p = 0.000$). In other words, executives display a statistically significantly higher property price (Eur 148,035.7) than do factory workers (Eur 96,704.46).

Table 6: The Distribution of Property with Respect to Prices and the Buyer's Social Class

	executive	intermediate professions	employees	craftsman	factory workers	retired	farmers	others	Total
property prices									
below the median	353	1,302	1,133	334	1,431	336	72	114	5,075
%	28.04	45.02	52.72	42.44	63.01	34.75	41.14	53.02	47.36
above the median	906	1,590	1,016	453	840	631	103	101	5,640
%	71.96	54.98	47.28	57.56	36.99	65.25	58.86	46.98	52.64
Total	1,259	2,892	2,149	787	2,271	967	175	215	10,715
%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note:This table presents the distribution of property prices with respect to the median price, and to socioeconomic categories, in absolute numbers and in % of each social category.

The increase of property prices comes from an increase of the net demand.[6] If the net demand for cheap dwellings is mainly represented by factory workers, the decrease of prices for flats follows a decrease of their net demand, meaning that factory workers want to leave the area.

These results provide some indications of the relationship between the refinery's closure and house prices. Unless it is assumed that owners of cheap properties are less informed about the impact of pollution, then the objectiveness of the damage function versus the perception derived the hedonic pricing analysis does not explain differences in the results across property price category. The perception of the decrease in health risks may indeed be smaller than the real decrease in health risks, because of imperfect information as explained in the theoretical section previously. Besides, because their budget constraints are tight, the buyers of cheap flats may face stronger spending constraints than others. In the case of the refinery's closure, the shock has not only had an impact on pollution, but also on economic activity. Even if they were aware of air pollution reduction, the economic effect is larger in relative terms for owners/buyers of cheap dwellings (positioned below the median in the subsample of Table 5, than the environmental effect. Managers, who are sensitive to the reduction in pollution, may prefer to stay in Dunkirk. Factory workers, on the other hand, who are sensitive to the economic shock, may prefer to sell their properties in Dunkirk. In contrast, the environmental effect is larger in relative terms for owners/buyers of expensive properties than the economic effect. A basic finding in the literature is that income tends to influence the willingness to pay for the environment, positively and significantly (Hokby and Soderqvist, 2003). Willingness to pay for the environment may differ with the level of income. In this context, people buying expensive dwellings may be more sensitive to pollution than people buying cheap dwellings.

[6]This is due to an increase of the household demand who want to live in the area or an decrease of the household demand who want to leave the area

Apart from such complexity in population behavior, monetary evaluation with hedonic pricing analysis alone cannot provide an absolute value (MaslianskaÃŕa-Pautrel, 2009). Hedonic results can be used by policy-makers, providing a careful interpretation and/or comparison with other methods such as the evaluation of sanitary costs.

5.3 Monetary evaluation

I derive an approximation of the cost of pollution in terms of labor by looking at the dose-response function. [7] The ExternE project provides a monetary evaluation that I take into account to derive an approximation of the cost of pollution. In ExternE, the working hypothesis has been to use the exposure response functions for particles and for O3 as a basis for observation. Effects of SO_2 are assumed to arise indirectly from the particulate nature of nitrate and sulfate aerosols, and they are calculated by applying the particle exposure response (ER) functions to these aerosol concentrations. In this context, the particle exposure response (ER) to SO_2 is used to obtain an approximation of the ExternE cost. A large number of studies focusing on the economic value of reducing SO_2 and related pollutants find that a high share of the quantified health benefits are associated with a reduction in mortality. More than 80% of monetized benefits were attributed to reductions in premature mortality (Krupnick et al., 2002). Thus, I examine the possible cost of chronic mortality using exposure response functions from the ExternE project. The ExternE numbers, used here, are based on the years of life lost (YOLL) per death. Exposure response functions from the ExternE project are used to compute mortality loss.

The slope of the concentration response function [cases/(person year $\mu g/m^3$)] (SCR) is taken here as the slope for chronic mortality for France (all causes, male + female), and

[7]The ExternE project (External Costs of Energy) is a project of the European Commission which aims to measure the damages to society that are not paid for by its main actors and to translate these damages into a monetary value.

equals 2.77E(-4). Assuming a cost for Year of Life Loss of Eur 50,000 per annum, then the 5 micrograms of pollution cost Eur 12,683 per person per year. Assuming a population of 376,439 in Dunkirk, in 2009 (INSEE), then the total cost amounts to Eur 26.07 million per year. In other words, there is a yearly cost difference evaluated at approximately Eur 26.07 million in terms of chronic mortality, before and after the refinery closure in Dunkirk.
In comparison, property prices above the median increase by nearly 2%, after the refinery closure, which suggests an average benefit of approximately Eur 2,760 for each property transaction. Hence the benefits accrue to all house-owners as a wealth shock, equal to roughly 2% of property values. It should be noted that this gain underestimates the potential benefit for all properties. In fact, this potential benefit exists as a latent gain on every transaction that has not been realized. The hedonic priceing analysis ignores the effect of air pollution on the property market as a whole, as well as its long term effects. Thus, I further estimate the effect of closure with respect to the size of the property, in order to approximate the effect on the property market as a whole. Table 7 shows a positive effect for properties with at least 5 rooms. While the sign is positive, there is no significant effect when I consider properties between 2 and 4 rooms.

However, the effect is negative for properties with only one room, which reinforces the argument of the role of budget constraints given above. INSEE states there were 89,707 properties in Dunkirk in 2009, out of a total of 1,789,875 in the Nord Pas-de Calais as a whole. 786,372 homes have 5 or more rooms, while 62,224 have one room. 45% of properties have 5 rooms at least in the Nord Pas-de Calais, which means that approximately 40,360 properties in Dunkirk also have 5 rooms. Property prices for these homes increased by nearly 5 percent after the refinery closure with respect to Table 7. This suggests there has been an average benefit of approximately Eur 8,460 for each transaction. The mean price for this category of homes is Eur 169,249. The potential benefit for all properties in Dunkirk thus amounts to approximately Eur 340 million.

Table 7: The Effect of the Closure with Respect to the Size of a House

VARIABLES	(1) 1 room	(2) 2 rooms	(3) 3 rooms	(4) 4 rooms	(5) 5 or more rooms
post_treatment	-0.167***	0.0224	0.00306	0.0147	0.0570***
	(0.0417)	(0.0144)	(0.0178)	(0.0337)	(0.0124)
Un	0.000517	-0.0857*	-0.0576***	-0.00151	-0.0293
	(0.0975)	(0.0410)	(0.0102)	(0.0192)	(0.0180)
attic	-0.201	-0.0735	-0.0309	-0.0502**	-0.0204
	(0.156)	(0.0404)	(0.0215)	(0.0149)	(0.0114)
balcony	-0.0424	0.124***	0.204***	0.212***	0.134
	(0.0582)	(0.0344)	(0.0369)	(0.0522)	(0.0964)
srf_parking	0.0285***	0.00458	-0.000282	0.000963	-0.00213
	(0.00421)	(0.00251)	(0.00181)	(0.000637)	(0.00131)
srf_hab_init	0.0126***	0.0121***	0.00918***	0.00796***	0.00466***
	(0.00319)	(0.000977)	(0.000616)	(0.000888)	(0.000193)
less_5_years	1.135***	0.424***	0.389***	0.407***	0.250***
	(0.157)	(0.0668)	(0.0372)	(0.0263)	(0.0154)
Constant	10.50***	11.78***	11.60***	11.04***	11.80***
	(1.284)	(0.490)	(0.162)	(0.275)	(0.227)
Observations	254	817	1,467	2,461	5,273
R-squared	0.758	0.629	0.604	0.456	0.445

Note: This table presents the effect of the refinery's closure on migration, by social category. Robust standard errors in parentheses. Statistical significance is denoted by: *** p<0.01, ** p<0.05, * p<0.1

These estimates suggest that the yearly benefit of approximately Eur 26.07 million in terms of chronic mortality is much smaller than the perception of the potential benefit for all properties in Dunkirk. Nevertheless, disutility from degraded health is only one part of people's perception of air pollution. The literature also emphasizes more broadly the cost of air pollution. Not only may the health risk due to air pollution be a source of disutility but so may physical objects present in an environment: the view of a factory chimney, smoke or possible odor may also have an impact on the perception of populations living near a refinery. SO2 has a potential impacts on plants (crop loss), as well as on buildings and materials (corrosion and erosion) (Krupnick et al., 2002). Individuals' valuations of the lower health risks and any effect on neighborhood aesthetics may be reflected in the price differential associated with proximity to a refinery. The difference between the health benefits and the price differential may be interpreted as a combination of individual valuations of neighborhood aesthetics and people's perception of a decrease in health risks. In addition, the health costs estimated are below the change in prices observed but mortality costs are likely to be much higher.

6 Conclusion

This paper tests the short term effect of sulfur dioxide (SO_2) and the overall impact it has on property prices. The first aim of this work is to assess the impact of a reduction in air pollution on property prices, for municipalities that actually experienced such a fall in pollution, following the cessation of operations by the oil refinery in Dunkirk (in the north of France), in September 2009. With a panel dataset, the best way to isolate the causal effect of the reduction in SO concentration due to the closure of the refinery is to examine outcome differences between Dunkirk and its counterparts, overtime. I look at the effects of closure on local measures of SO_2 concentration, and address several longstanding issues dealing with non-random selection and behavioral responses to air pollution that may bias previous studies.

The first results indicate that the closure leads to a reduction in the concentration of SO_2, suggesting that strengthening regulations on SO_2 pollution would yield additional benefits in general. However, the estimations here also show that hedonic pricing analysis does not always reflect the economic benefits of this improvement in air quality. It suggests that failing to incorporate different price segments of the market into a hedonic approach leads to biased estimates. While buyers of expensive dwellings do respond to the environmental improvement resulting from refinery closure, the willingness of buyers to pay for cheap properties does not reflect the economic benefits of air quality.

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