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## Industrial Risks and Housing Prices

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# Industrial Risks and Housing Prices<sup>\*</sup>

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## Abstract

Housing prices can decrease because of proximity to hazardous industrial plants. This effect depends on households' perception of risk and can so be modified by events that change risk perception, such as technological risk prevention plans in France. The impact of these plans is difficult to estimate because their implementation in urban zones is very recent. However, the study of other events modifying risk perception provides partial answer.

This paper studies areas in the vicinity of hazardous industrial plants near Bordeaux, Dunkirk and Rouen. Applying hedonic price method enables to estimate the effect of proximity to hazardous industrial plants on housing prices. Results suggest that these price differences are modified neither by local incidents, the AZF accident, information policies, nor by the implementation of the technological disasters insurance system.

*Keywords* : environmental public policies, industrial risk, land use, hedonic price method.

*JEL classification* : Q51, Q58, R52.

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# 1 Introduction

As in practice households partly bear the cost of a potential industrial accident,<sup>1</sup> housing prices can decrease because of proximity to hazardous industrial plants. Numerous empirical works show that exposure to industrial risks or pollutions decreases the price of dwellings. Different industrial activities have been studied to that respect, in particular chemistry (Carroll et al. (1996), Decker et al. (2005)), waste treatment and storage (see Farber (1998) for a review), storage and distribution of oil (Flower and Ragas, 1994) and of natural gas (Boxall et al., 2005), proximity to an oil pipeline (Simons, 1999) or proximity to an industrial area (Travers (2007), Travers et al. (2009), Sauvage (1997)).

The effect of industrial risk on housing prices depends on households' perception of risk and can so be modified by events that change risk perception. Several empirical works show that real estate prices can be so significantly modified by insurance,<sup>2</sup> information policies (Kohlhase (1991), Maani (1991), Gayer et al. (2000)) or prevention policies, such as technological risk prevention plans in France. These plans were created in 2003 in reaction to the AZF accident on September 21, 2001 in Toulouse.<sup>3</sup> They define high-risk areas and prevention measures, in particular land use limitation near hazardous plants. The 420 plans concern more than 600 plants over more than 900 jurisdictions (communication of the French Ministry of Ecology). Some local players fear that the implementation of these plans will decrease housing prices in high-risk areas (Chabbal, 2005).<sup>4</sup> This price modification is difficult to estimate because the few plans implemented in urban zones are recent.<sup>5</sup> However, the study of other events modifying risk perception provides partial answer.

This paper studies three different areas around industrial plants in France near Bordeaux, Dunkirk and Rouen. The three areas are very different in terms of risk perceptions (Table 1). The gunpowder factory near Bordeaux is not necessarily perceived as hazardous by neighboring populations. Indeed, it is a former military plant; only barbed wire can be seen from some places of the study area. Furthermore, the plant is wide (650 buildings over 350 hectares); risk is so perceived as contained. The only nuisance associated to the plant is the transportation of hazardous materials on a precise and limited route.<sup>6</sup> On the contrary, chemical activities near Dunkirk or Rouen are clearly identified as hazardous by local populations. Buildings, chimneys or at least plumes of smoke can be seen from every point of the study area near Dunkirk. However, the presence of a nuclear plant in Gravelines (18 km from Dunkirk) can overshadow the exposure to industrial risks here studied. Near Rouen, chimneys or silos are hidden by landscape in some points of the study area.

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1. Damages certainly imply the liability of the industrialist, but compensation can be delayed and remain partial. In particular, some physical and moral damages cannot be repaired.

2. Flood insurance shapes real estate prices (MacDonald et al. (1990), Harrison et al. (2001), Morgan (2007) and Bin et al. (2008)).

3. See law n<sup>o</sup>2003-699 of July 30, 2003 relative to prevention of technological and natural risks and to damages repair.

4. According to Chabbal (2005), local players also fear an increase of the price of technological disasters insurance for households. This fear is not justified, because insurance of households is an insurance for victims: it advances repayment expenses and covers the risk of no responsible identification or its insolvency. Technological disasters premium amounts to a few euros per year. On the contrary, the insurance price for industrialists has strongly increased after the AZF accident (Picard and Chemarin, 2004).

5. "On September 1st, 2010, 335 plans over 420 were initiated and 50 were implemented" (press release by Chantal Jouanno, French Minister of State for Ecology, October 14, 2010, our traduction).

6. Source: reports by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France.

TABLE 1 – The three studied areas

Jurisdiction	INSEE code	Population (a)	Population density (a)	Percentage of built area (b)	Average tax revenue (a)	Sports and sociocultural facilities (c)	Distance to labor pool (d)	Nuisances in terms of air quality / odor (due or not to the plants) (e) / complains for sound pollutions due to the plants (f)	Industrial plants
<i>Bordeaux</i>									
Le Haillan	33200	8 378	904 per sq km	8%	26 817 €	14	5.9 km	-	
Martignas-sur-Jalles	33273	6 633	251 per sq km	2%	29 005 €	27	9.2 km	-	
Mérignac	33281	65 469	1 359 per sq km	9%	23 181 €	72	4.4 km	-	
Saint-Aubin-de-Médoc	33376	5 550	159 per sq km	1%	41 577 €	12	11.1 km	-	2 high-level Seveso plants.
Saint-Médard-en-Jalles	33449	26 984	315 per sq km	3%	27 599 €	48	4.8 km	-	Activities : gunpowder and explosives manufacture. Risk : explosion.
Le Taillan-Médoc	33519	8 668	571 per sq km	5%	30 412 €	14	4.9 km	-	
<i>Dunkirk</i>									
Coudekerque-Branche	59155	22 994	2 515 per sq km	11%	18 641 €	23	4.3 km	-	5 plants : 4 Seveso, 1 subject to authorization.
Dunkirk	59183	69 274	1 855 per sq km	12%	20 218 €	18	4.1 km	-	Activities : storage of oil products, manufacture of lubricants and pharmaceutical products. Risks : explosion, fire, toxic effects.
Fort-Mardyck	59248	3 586	2 543 per sq km	13%	18 610 €	7	9 km	Odor, complains	
Saint-Pol-sur-Mer	59540	22 100	4 299 per sq km	16%	14 711 €	14	6.2 km	Complains	
<i>Rouen</i>									
Grand-Couronne	76319	9 346	552 per sq km	5%	20 083 €	18	20.5 km	-	13 plants : 2 high-level Seveso, 1 Seveso, 5 subject to authorization and to an emergency plan, 5 authorized.
Hautot-sur-Seine	76350	9 346	160 per sq km	1%	26 423 €	2	19.3 km	Odor	Activities : storage of liquid petroleum gas and refining, paper manufacture, production of Diester oil (biodiesel) and liquid carbon dioxide, goods transportation, perfumes storage and warehouses. Risks : explosion, fire, toxic effects.
Moulineaux	76457	881	238 per sq km	2%	21 287 €	10	20.6 km	-	
Petit-Couronne	76497	8 690	679 per sq km	5%	19 638 €	28	21.1 km	Air quality, odor	
Sahurs	76550	1 310	117 per sq km	1%	27 017 €	5	26.8 km	-	
Val-de-la-Haye	76717	751	74 per sq km	1%	23 673 €	5	20.5 km	Air quality, odor	

Sources : (a) INSEE, (b) building database of the Geographical National Institute, (c) topology database of the Geographical National Institute, (d) Sitrinet, (e) Air Quality Agency, (f) Regional Office for Environment, Planning and Housing.

All local and national events that can modify risk perception during the study period, that is between 2000 and 2008 inclusive, are considered (Table 2).<sup>7</sup> Local events are accidents and information mechanisms. Only one accident happened on January 12, 2007 at Rubis Terminal (storage of liquid flammable and agrochemical products) near Dunkirk.<sup>8</sup> Local policies include the distribution of information leaflets, the update of the emergency plan for households and the implementation of local committees for information and consultation. Relevant national events are the AZF accident and the law steps during the study period. The 2003 law created not only technological risk prevention plans, but also the technological disasters insurance system. The aim of this system is to manage the basic coverage for victims by avoiding long litigation and by covering the residual risk of no responsible identification. In addition, by this very same law, the seller or the landlord has to precise in writing whether his dwelling is located in an area covered by a technological (or natural) risk prevention plan.<sup>9</sup> Mandatory information for buyers and tenants was implemented on June 1st, 2006.

TABLE 2 – Local and national events that can modify industrial risk perception during the study period

Year	Bordeaux	Dunkirk	Rouen	National level
2001	-	-	-	AZF accident
2002	-	Information leaflets	-	-
2003	-	-	-	Law
2004	-	Update of the emergency plan for households	-	-
2005	-	-	Creation of local committee for information and consultation	-
2006	-	Creation of local committee for information and consultation + information leaflets about the emergency plan for households	-	Mandatory information for buyers and tenants
2007	-	Accident	Information leaflets about the emergency plan for households (*)	-

(\*) Distribution of information leaflets in all jurisdictions except Moulineaux.

Source : reports by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France.

Housing prices decrease with respect to the proximity of hazardous plants near Dunkirk and Rouen. Results indicate that these price differences are modified neither by local incidents, the AZF accident, information policies, nor by the implementation of the technological disasters insurance system.

Our analysis follows hedonic price method formalized by Rosen (1974). The author considers that a dwelling is defined by  $K$  attributes  $Z = (z_1, \dots, z_K)$ . Dwelling price corresponds to the combination of attributes at their implicit prices.  $Z \rightarrow P(Z)$  is the hedonic price

7. A technological risk prevention plan has been initiated after the end of the study period : on December 15, 2009 near Bordeaux, on February 20, 2009 near Dunkirk and on April 14, 2010 near Rouen.

8. Neighboring populations saw flames and plumes of smoke. The accident triggered an emergency plan inside the plant and required the intervention of civil fire brigades.

9. If so, he should also mention whether the dwelling has been damaged by a technological (or natural) disaster. A technological disaster is defined by the law as a non nuclear accident damaging an important number of buildings (more than 500 dwellings made as uninhabitable) and happening either in a plant classified for the environment protection, in an underground storage of hazardous products or on the occasion of hazardous materials transportation (Insurance Code, sections L128-1 and R128).

function. A household of income  $w$  maximizes his utility function  $U(y, Z)$ , where  $y$  denotes money, under his budget constraint  $w = y + P(Z)$ .

$$\begin{aligned} \max_{y, z_1, \dots, z_K} & U(y, z_1, \dots, z_K) \\ \text{s.t. } & w = y + P(z_1, \dots, z_K). \end{aligned} \quad (1)$$

Households maximize their utility by equalizing their marginal rate of substitution between attribute  $z_k$  and money with the marginal price  $\partial P(Z)/\partial z_k$ , henceforth called implicit price.

$$\frac{\partial P(Z)}{\partial z_k} = \frac{U_{z_k}(y, Z)}{U_y(y, Z)}. \quad (2)$$

This marginal rate of substitution corresponds to household's marginal willingness to pay for increasing  $z_k$  by one unit. Thus, estimation of the hedonic price function provides an estimation to households' marginal willingness to pay to go one more meter away from the hazardous plants.

The main contribution of this paper is the quality of data. Indeed, hedonic price method requires data on price and characteristics of the dwellings. These characteristics are intrinsic (number of rooms, of bathrooms, etc.) and extrinsic (proximity to shops and public utilities, exposure to risks or pollutions, etc.). The price of the dwelling and its intrinsic characteristics come from PERVAL notarial data in the years 2000, 2002, 2004, 2006 et 2008. Following Travers et al. (2009), only dwelling purchases (as opposed to rentings) have been considered. Detailed data relative to extrinsic characteristics of the dwelling have been collected, standardized and merged with notarial data : the proximity of the dwelling to shops and public utilities, its exposure to industrial risk, other risks or pollutions (Table 3). Other characteristics of the jurisdiction have been collected and merged (Table 1). The database here used is so unique and much more complete than the ones used for similar studies.

An important practical question for data collection was the definition of the study area. It results from a tradeoff between two requirements : the area has to be limited enough to correspond to an homogenous real estate market and broad enough to include dwellings far from the plants than can be considered as a control group. This second criterion aims to limit a potential selection bias : households living near plants may have different unobserved characteristics and may so not be a representative sample of the local population.

The choice of variables measuring risk perception is also crucial. In the literature, three types of variables have been used (Travers et al., 2009) : the effective distance between the dwelling and the plant (Kohlhase (1991), Carroll et al. (1996)), a dummy for location in the exposed area (Flower and Ragas, 1994), this area being defined by physical or administrative criteria, or quantitative variables that traduce a gradation of exposure to risk or pollutions created by the plant (Boxall et al. (2005), Decker et al. (2005)).

We use here effective distance between the dwelling and the plant. We consider "authorized plants" (subject to the regime of classified plants for the environment protection) and we distinguish among them "highly hazardous plants" (mainly Seveso plants). Furthermore, four exposed areas had been considered to test for an additional effect of location in these areas on housing prices. The considered areas were the zone of the emergency plan for households and the areas of control for future land use : Z1 area (which corresponds to the area with lethal damages in the case of accident), Z2 (irreversible damages) and Z3 area (breaking of windows). Our analysis could not be based on these variables as these zones are not wide enough to include a large number of transactions during the study

period.<sup>10</sup> Finally, as a same level of risk exposure can be more or less felt depending on the perception of industrial pollutions, we have built a dummy for dwellings near Rouen for view of plants from the dwelling. Other elements relative to pollution perception have also been collected at the jurisdictional level (air or odor pollutions, complains because of sound pollutions) and enable to interpret the effect of the jurisdiction on housing price.

TABLE 3 – Data at the dwelling level

<i>Intrinsic characteristics</i> (a)	<i>Extrinsic characteristics</i>	
Price (including tax) (*)	Distance to market square	(b), (c)
House or apartment	Distance to drugstore	(b), (c)
Less than 5 years	Distance to food shop	(b), (c), (d)
State (o)	Distance to bus stop	(e)
Living space (*)	Distance to park	(e)
Number of rooms	Distance to nursery or primary school	(d), (f)
Number of bathrooms	Distance to high school	(d), (f)
Number of parking lots	Distance to highly dangerous plants (†)	(g)
Presence of terrace	Distance to authorized plants (‡)	(g)
Presence of balcony	View of industrial plants (near Rouen) (◊)	(f)
Presence of elevator	Location in a land use control area (Z1, Z2, Z3)	(h)
Presence of swimming pool	Location in the zone of the emergency plan for households	(i)
Presence of basement	Location in an area exposed to natural risks (▷)	(h)
Presence of cellar	Location in an area exposed to other risks (▷)	(h)
Presence of annexes	Location in a residual pollution area	(j)
Presence of outbuildings	Sound exposure to a land transport facility	(k), (l)
Area of land	Sound exposure to an air transport facility	(k), (l)
	Location in environmental protection area	(h)
	Location in conservation easement area	(h)

Sources : (a) PERVAL, (b) Chambers of Commerce and Industry database, (c) jurisdictional database, (d) phone book, (e) topology database of National Geographical Institute, (f) building database of National Geographical Institute, (g) database for classified plants per jurisdiction, (h) land use plan, (i) prefecture, (j) Regional Office for Environment, Planning and Housing, (k) sound map of Departmental Office for Territories and Sea, (l) sound map of Technical Studies Center of Public Works.

Notes : each distant to a facility is built as the distance to the closest facility.

(\*) Database is essentially composed by older property. Thus prices have been discounted by the seasonally adjusted price index for older property. This index (built by INSEE) is based on PERVAL database.

(o) Good, works to do or to renovate.

(\*) Living space is filled in for 81% of observations near Bordeaux, 80% near Dunkirk and 62% near Rouen. The imputed value for missing values is the average living space over the five closest neighboring dwellings with the same number of rooms. Price per square meter is thus inferred.

(†) Most hazardous plants among the classified plants for the environment protection (mainly Seveso plants).

(‡) Plants subject to the regime of classified plants for the environment protection.

(◊) View from the dwelling of red and white Pétroplus chimney or of Senalia silo.

(▷) Area of servitude or notification.

## 2 Model

Estimation of the hedonic price function enables to measure the effect of proximity to hazardous plants on housing prices and to what extent considered events modify this effect.

10. For example, there is no transaction in the land use control areas during the study period near Bordeaux or Dunkirk; similarly, there is no transaction in the zone of the emergency plan for households near Bordeaux.

## 2.1 Estimation problems

Some estimation problems are specific to hedonic price method. First, functional form of hedonic price function depends on underlying assumptions on demand and supply. Unless making very specific assumptions, the hedonic price function is not linear and has no known explicit form (see Freeman (2003) for a review on hedonic price method).

Second, there can be a spatial dependency, called *spatial autocorrelation*, between geographical observations. This corresponds to effects of close neighborhood. The dwelling price can directly depend on the price of former neighboring transactions. This dependency is so called *spatial lag*. For example, the buyer gets information relative to former neighboring transactions (on the web or via real estate agencies) and uses these elements to establish his willingness to pay for the dwelling. Spatial autocorrelation can also result from the error term, because some omitted or unobserved variables present a spatial configuration. With this dependency called *spatial errors*, estimation is potentially biased. For example, if areas close to industrial plants are characterized by strong criminality and if households care for safety, then omitting safety variables leads to an overestimation of households' willingness to pay to reduce their exposure to industrial risk. Note that here, historical links between cities and industries suggest that the most exposed areas are not the most deprived,<sup>11</sup> but other omitted variables can bias results.

## 2.2 Answers brought by literature

Literature brings answers to these estimation problems.

To choose the functional form, the usual approach consists in narrowing this form as less as possible and then in determining the form that explains at best the housing price. The wide majority of articles applying hedonic price method use Box-Cox transformations for the dependent variable (housing price) or for continuous regressors (Kuminoff et al., 2010). According to Box and Cox (1964), the transformation  $x^{(\beta)}$  of variable  $x$  is

$$x^{(\beta)} = \begin{cases} \frac{x^\beta - 1}{\beta} & \text{if } \beta \neq 0, \\ \log(x) & \text{if } \beta = 0. \end{cases} \quad (3)$$

This transformation generalizes log or power functions. However, the aim of this paper is not to estimate the hedonic price function, but only the implicit price of one characteristic of the dwelling. Given this goal, several articles warn of a very elaborated specification. Cassel and Mendelsohn (1985) and Cropper et al. (1988) show that the form that explains at best the housing price does not necessarily lead to a more precise estimation of the implicit price of the considered characteristics.<sup>12</sup>

The majority of articles consider one or several of the following models : the linear model (Lin), the log-linear one (Loglin), the log-log one (Loglog), the quadratic one (Quad), the linear Box-Cox one (BoxCox) and the quadratic Box-Cox one (QuadBoxCox).  $K$  denotes the set of regressors and among them  $K_d$  is the set of discrete regressors and  $K_c$  is the set of continuous ones.

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11. Near Bordeaux, jurisdictions in the neighborhood on the gunpowder factory were initially developed thanks to its activity ; urban development was then explained by attraction to Bordeaux center. Near Dunkirk, after World War II, urbanization was realized around industrial activities which were not perceived as hazardous (shipyards, steel industry) ; hazardous plants (chemistry, petrochemistry) only appeared in Dunkirk harbor in the 1970s. Near Rouen, cities get closer and closer to the plants.

12. It corresponds to a typical tradeoff between bias et variance : the number of estimated parameters decreases the bias in the implicit prices estimation but increases their variance.



Linear	$P$	$= \sum_{k \in K} p_k z_k,$	(Lin)
Log-linear	$\ln(P)$	$= \sum_{k \in K} p_k z_k,$	(Loglin)
Log-log	$\ln(P)$	$= \sum_{k \in K_c} p_k \ln(z_k) + \sum_{k \in K_d} p_k z_k,$	(Loglog)
Quadratic	$P$	$= \sum_{k \in K} p_k z_k + \sum_{(k,k') \in K^2} \frac{p_{kk'}}{2} z_k z_{k'},$	(Quad)
Linear Box-Cox	$P^{(\beta_p)}$	$= \sum_{k \in K_c} p_k z_k^{(\beta_z)} + \sum_{k \in K_d} p_k z_k,$	(BoxCox2)
Quadratic Box-Cox	$P^{(\beta_p)}$	$= \sum_{k \in K_c} p_k z_k^{(\beta_z)} + \sum_{k \in K_d} p_k z_k + \sum_{(k,k') \in K_c^2} \frac{p_{kk'}}{2} z_k^{(\beta_z)} z_{k'}^{(\beta_z)}$ $+ \sum_{(k,k') \in K_c \cdot K_d} \frac{p_{kk'}}{2} z_k^{(\beta_z)} z_{k'} + \sum_{(k,k') \in K_d^2} \frac{p_{kk'}}{2} z_k z_{k'}.$	(QuadBoxCox)

Note : the number for the linear Box-Cox model corresponds to the number of estimated Box-Cox coefficients. There are two of them :  $\beta_p$  for the dependent variable and the same  $\beta_z$  for all continuous regressors.

Some articles use simulated data (Cropper et al. (1988), Kuminoff et al. (2010)). Model is said to perform if it corresponds to a small measurement error, i.e. a small difference between the implicit price as estimated and the one initially simulated. Cropper et al. (1988) compare estimation errors for the implicit prices between the different considered functional forms, with and without omitted variables. In their article, omitted variables are intrinsic characteristics of the dwelling. They show that “when all attributes are observed, linear and quadratic Box-Cox forms produce lowest mean percentage errors ; however, when some attributes are unobserved or are replaced by proxies, linear and linear Box-Cox functions perform best.”

Thus, Cropper et al. (1988) recommend to estimate a linear Box-Cox function where all transformed regressors have the same Box-Cox coefficient, except for the regressors of interest. Palmquist (1991) and Freeman (2003) also suggest to estimate one coefficient  $\beta_i$  for the regressor of interest and one same coefficient  $\beta_z$  for all other continuous regressors. We will keep this functional form on the basis of likelihood criteria.

Still with simulated data, Kuminoff et al. (2010) revisit Cropper et al. (1988) results and take into account the increasing size of samples and the evolution of omitted variables (most of the time, extrinsic characteristics of the dwelling). With spatial omitted variables, estimation bias increase in the two quadratic models but these models remain the most performing ones. Furthermore, Kuminoff et al. (2010) show that adding fixed spatial effects pleads for the estimation of flexible functional forms. This addition enables to take into account a potential *spatial heterogeneity*, i.e. the existence of different local real estate markets. It enables this way to capture price variations due to spatial variables potentially omitted. Kuminoff et al. (2010) show that, when adding fixed spatial effects (dummies for *census tract*), estimation biases due to omitted spatial variables disappear almost entirely for every functional form and that variance is reduced.

From the chosen functional form, spatial autocorrelation can be estimated and if needed corrected. Different models corresponding to different types of spatial dependency (spatial errors, spatial lag) or combining them can be estimated. Specific tests enable to compare these models (Figure 1).

## 2.3 Comparing estimated models

The linear, log-linear, log-log and linear Box-Cox forms are estimated. Quadratic forms are not considered because the number of variables becomes too important in comparison with the number of observations and because the majority of crossed variables are not significant (in particular the ones which imply the regressors of interest). Following Palmquist (1991) and Freeman (2003), the linear Box-Cox model is estimated with one, two and three coefficients. By denoting  $K_i$  the set of regressors of interest :

$$\begin{array}{llll}
 \text{Linear} & P & = \sum_{k \in K} p_k z_k, & (\text{Lin}) \\
 \text{Log-linear} & \ln(P) & = \sum_{k \in K} p_k z_k, & (\text{Loglin}) \\
 \text{Log-log} & \ln(P) & = \sum_{k \in K_c} p_k \ln(z_k) + \sum_{k \in K_d} p_k z_k, & (\text{Loglog}) \\
 \text{Linear Box-Cox 1} & P^{(\beta)} & = \sum_{k \in K} p_k z_k, & (\text{BoxCox1}) \\
 \text{Linear Box-Cox 2} & P^{(\beta_p)} & = \sum_{k \in K_c} p_k z_k^{(\beta_z)} + \sum_{k \in K_d} p_k z_k, & (\text{BoxCox2}) \\
 \text{Linear Box-Cox 3} & P^{(\beta_p)} & = \sum_{k \in K_i} p_k z_k^{(\beta_i)} + \sum_{k \in K_c \setminus K_i} p_k z_k^{(\beta_z)} + \sum_{k \in K_d} p_k z_k. & (\text{BoxCox3})
 \end{array}$$

Note : the number given for the linear Box-Cox models corresponds to the number of estimated Box-Cox coefficients.

Fixed spatial effects are added via dummies for jurisdictions. The linear Box-Cox 3 model is the one that explains at best housing prices near Dunkirk according to the AIC ; near Bordeaux and Rouen, the linear Box-Cox 2 model is the one that fits at best data, but the AIC of the linear Box-Cox 2 and 3 models are very close (Table 4). As this study aims to estimate the implicit price of distance to plants, we keep the linear Box-Cox 3 model which allows the most flexible link between price and regressors of interest.

From the linear Box-Cox 3 model, models traducing or combining different types of spatial dependency are estimated and compared (Figure 1 and Table 5). We keep a linear Box-Cox 3 model with spatial errors near Bordeaux and Dunkirk and a Kelejian-Prucha linear Box-Cox 3 near Rouen.

## 2.4 Effect of events that can modify risk perception

How to measure the effect of these events on the implicit price of distance to plants ? First, we assume that the considered events that can modify risk perception (Table 2) do not change the equilibrium price equation. This is all the more realistic in that exposure to industrial risk affects only a fraction of observations and in that these events do not radically change risk perception.

Let's then consider that there are only two zones, one exposed and one safe. The exposed zone is treated in the sense that is concerned by events modifying risk perception ; the safe zone corresponds to the control group. The *difference in differences* method (Greenstone and Gayer, 2009) can be then applied to measure the evolution of the implicit price for the location in the exposed area : it consists in comparing the price difference between the two areas, that is the price for location in the safe area, before and after the event. This would require to cross the dummy for location in exposed area with a dummy for transactions occurring after the event, and to add fixed temporal effects. If prices are discounted, significant coefficients of fixed temporal effects traduce a uniform change on the real estate market. Note that this way we only control for concomitant events that would uniformly

TABLE 4 – Comparison of functional forms

Functional form	$\beta_p$	$\beta_z$	$\beta_i$	Parameters	Log-likelihood	AIC
Bordeaux						
Linear	1	1	1	36	-21 909	43 891
Log-linear	0	1	1	36	-21 828	43 728
Log-log	0	0	0	36	-21 753	43 577
Linear Box-Cox 1	0.4	1	1	37	-21 766	43 606
Linear Box-Cox 2	0.4	0.1	0.1	38	-21 689	43 455
Linear Box-Cox 3	0.4	0.1	0.9	39	-21 689	43 456
Dunkirk						
Linear	1	1	1	24	-13 152	26 351
Log-linear	0	1	1	24	-13 239	26 525
Log-log	0	0	0	24	-13 205	26 458
Linear Box-Cox 1	0.7	1	1	25	-13 135	26 320
Linear Box-Cox 2	0.7	0.2	0.2	26	-13 106	26 263
Linear Box-Cox 3	0.7	0.1	1.2	27	-13 097	26 247
Rouen						
Linear	1	1	1	26	-9 575	19 202
Log-linear	0	1	1	26	-9 604	19 260
Log-log	0	0	0	26	-9 599	19 250
Linear Box-Cox 1	0.5	1	1	27	-9 517	19 089
Linear Box-Cox 2	0.5	0.4	0.4	28	-9 506	19 067
Linear Box-Cox 3	0.5	0.4	0.5	29	-9 505	19 069

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France. 1786 observations near Bordeaux, 1134 near Dunkirk and 810 near Rouen.

Note : the Akaike Information Criterion (AIC) enables to compare the likelihoods of the models by taking into account the number of estimated parameters :  $AIC = 2m - 2\ln(L)$  where  $m$  is the number of parameters and  $L$  the likelihood. The model that explains at best housing prices is so the one with the lowest AIC.

TABLE 5 – Tests for spatial autocorrelation

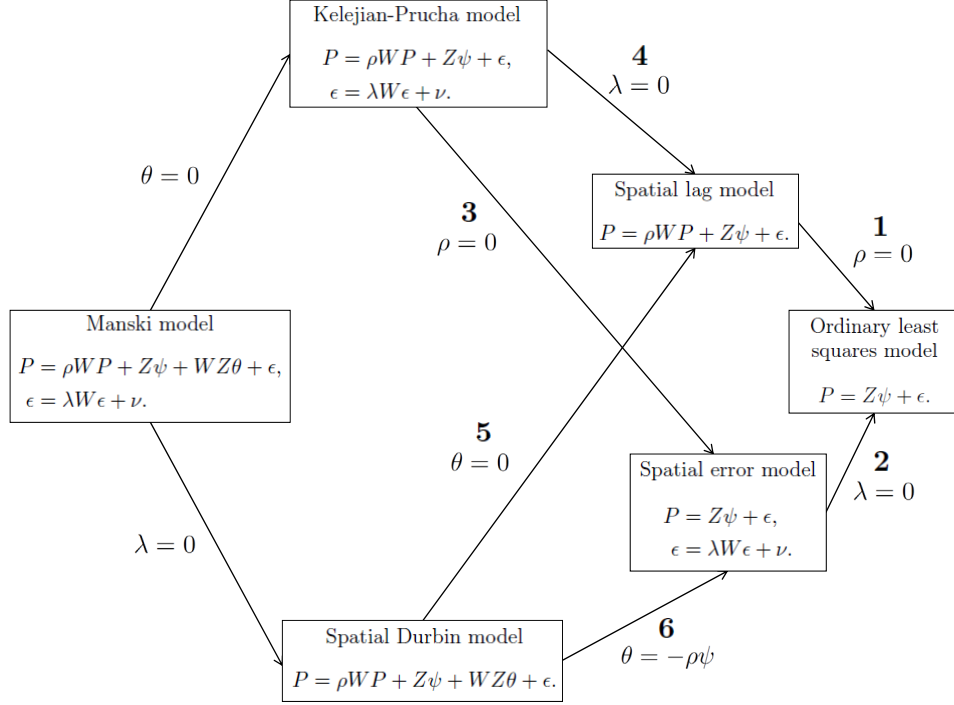
	Bordeaux	Dunkirk	Rouen
Moran's test	***	***	***
SARMA test	***	*	***
$\rho$ in <i>Lag</i>	<i>n.s.</i>	<i>n.s.</i>	<i>n.s.</i>
$\lambda$ in <i>Errors</i>	***	*	***
$\rho$ in <i>Kelejian-Prucha</i>	.	<i>n.s.</i>	*
$\lambda$ in <i>Kelejian-Prucha</i>	***	**	***
Test 1	<i>n.s.</i>	<i>n.s.</i>	**
Test 2	***	*	***
Test 3	<i>n.s.</i>	<i>n.s.</i>	**
Test 4	***	*	**

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France. 1786 observations near Bordeaux, 1134 near Dunkirk and 810 near Rouen.

Caption : ./ \*\* / \*\*\* : null hypothesis rejected at the threshold of 10%/5%/1%/0.1%.

Note : these tests are defined by Figure 1. They have been performed on the linear Box-Cox 3 model. Their results can be read the following way : the result of test 2 near Bordeaux is significant ; null hypothesis  $\lambda = 0$  is so rejected and the spatial errors model is so preferred to the ordinary least squares model.

FIGURE 1 – Link between the different models taking into account spatial dependency



Source : Elhorst (2010).

Notes :  $P$  denotes the housing price,  $Z$  the matrix of regressors,  $n$  the number of observations and  $W = (w_{ij})_{1 \leq i, j \leq n}$  the neighborhood matrix. Let's consider two transactions  $i$  and  $j$  are realized at dates  $t_i$  and  $t_j$  and  $d_{ij}$  away one from the other. Following Anselin (2002), we choose the weight of transaction  $j$  on transaction  $i$  as  $w_{ij} = \frac{1}{1+d_{ij}}$  if  $t_j < t_i$  and 0 otherwise. This way, we assume that only *previous* neighboring transactions weigh on the considered transaction.

The Manski model is the most general model but is difficult to interpret, as “the parameter estimates cannot be interpreted in a meaningful way since the endogenous  $[WZ]$  and exogenous  $[WP]$  effects cannot be distinguished from each other” (Elhorst, 2010).

The Durbin model badly converges because of collinearity between regressors and lagged regressors. This is due to the fact that many regressors are spatial variables. Thus, tests 5 and 6 which compare the Durbin model with respectively the spatial lag model and the spatial error model are not performed.

We denote  $LM_{M/CM}$  the Lagrange multiplier test between the model  $M$  and the constraint model  $CM$ . The tests for spatial autocorrelation are

$$\begin{aligned} \text{Moran's test :} & \quad \text{under } H_0 : \text{ no spatial autocorrelation, } T_{\text{Moran}} \sim \mathcal{N}(0, 1), \\ \text{SARMA test :} & \quad \text{under } H_0 : \rho = \lambda = 0, T_{\text{SARMA}} = LM_{\text{Kelejian-Prucha/OLS}} \sim \chi_2^2, \end{aligned}$$

where  $T_{\text{Moran}}$  is the centered and reduced value of  $I = \frac{\bar{\epsilon}' W \bar{\epsilon} / S_0}{\bar{\epsilon}' \bar{\epsilon} / n}$  with  $S_0 = \sum_i \sum_j w_{ij}$ .

We perform the following tests to compare the Kelejian-Prucha, spatial lag, spatial error and ordinary least squares (OLS) models :

$$\begin{aligned} \text{Test 1 :} & \quad (\lambda = 0), \text{ over } H_0 : \rho = 0, \quad LM_{\text{Lag/OLS}} \sim \chi_1^2 \\ \text{Test 2 :} & \quad (\rho = 0), \text{ over } H_0 : \lambda = 0, \quad LM_{\text{Error/OLS}} \sim \chi_1^2 \\ \text{Test 3 :} & \quad \forall \lambda, \text{ over } H_0 : \rho = 0, \quad LM_{\text{Kelejian-Prucha/Error}} \sim \chi_1^2 \\ \text{Test 4 :} & \quad \forall \rho, \text{ over } H_0 : \lambda = 0, \quad LM_{\text{Kelejian-Prucha/Lag}} \sim \chi_1^2. \end{aligned}$$

modify housing prices.<sup>13</sup>

Here however, the exposure is not defined by the dummy for location in one area but by the continuous variable that is the distance to plants. There are no two groups anymore but numerous groups, which are all the more treated in that they are closer to the plants. The method consists so in comparing the implicit price of distance to plants before and after the event. Following McMillen and McDonald (2004) and Travers et al. (2009), we cross the variable of distance to plants with a dummy for transactions occurring after the event. Otherwise, as explained, we discount prices (Table 3) and we add fixed temporal effects via dummies for the transaction year.

## 3 Results

### 3.1 Determinants of housing prices

Table 6 presents the results of the performed estimations.

**Intrinsic characteristics.** As expected, the price of the dwelling increases with respect to its state, the fact that it has been built since less than 5 years, its living space, its number of rooms, bathrooms or parking lots, the presence of a terrace, a balcony, a swimming pool, annexes or outbuildings or the area of land.<sup>14</sup>

**Extrinsic characteristics.** Unsurprisingly, near Bordeaux, distances to market square, drugstore or park decrease housing prices.<sup>15</sup> On the contrary, distances to food shop or bus stop increase housing prices. As the majority of inhabitants own a car, proximity to food shop or bus stop is probably less valued than in cities; they can even correspond to a sound pollution for very close dwellings. Similarly, near Dunkirk, distances to bus stop, park and high school raise the dwelling price. Note that sound pollution due to transport facilities does not modify significantly housing prices.

**Distance to hazardous plants.** Near Dunkirk and Rouen, proximity to highly dangerous plants decrease housing prices. Near Rouen, proximity to authorized plants has a significant additional effect. But view of plants does not significantly modify housing prices. Still near Rouen, location in Z1 area has a positive effect on prices, all other things being equal and in particular distance to plants. Forbidding building may protect from new neighbors and increase this way housing prices. Location in emergency plan area does not product a significant additional effect on prices. Indeed, the emergency plan for households is an administrative area that future buyers may ignore : information leaflets were distributed in 2006 near Dunkirk and in 2007 near Rouen (Table 2) but only inhabitants living in the area at the time of the distribution were informed.

Near Bordeaux, proximity to the gunpowder factory raises housing prices. As mentioned in Introduction, industrial risk is almost not perceived. Anstine (2003) shows that industrial risk, if neither visible nor perceived by odor, air pollution, does not modify real estate prices. Here, proximity to the gunpowder factory is even valued, perhaps because the neighborhoods of the plant are characterized by a green setting and are very quiet places. Besides, the presence of this industry may protect from new neighbors or activities.

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13. Local players have not mentioned any other concomitant event that would modify more or less prices depending of the dwelling location.

14. More surprisingly, apartments can be more expensive than houses all other things being equal. But this can be explained by the fact that on average apartments have a lower living space than houses and that this effect is already taken into account via the living space variable.

15. Distance to park and the fact that the park is at less than 500 meters both increase housing prices, but the magnitude of the latter variable is more important.

TABLE 6 – Estimation of the hedonic price function

	Bordeaux	Dunkirk	Rouen	Bordeaux	Dunkirk	Rouen
Intercept	<i>n.s.</i>	***	***	***	***	***
House or apartment ( <i>ref</i> : house)						
- apartment	***	***	<i>ex</i>	<i>ref.</i>	<i>ref.</i>	<i>ref.</i>
Less than 5 years	***	***	***	<i>n.s.</i>	<i>n.s.</i>	<i>ex</i>
State ( <i>ref</i> : missing)				<i>n.s.</i>	<i>n.s.</i>	<i>ex</i>
- good	<i>ex</i>	***	***	<i>n.s.</i>	<i>n.s.</i>	<i>ex</i>
- to renovate or works to do	***	***	***	<i>ex</i>	<i>ex</i>	***
Living space	***	***	***			<i>n.s.</i>
Number of rooms ( <i>ref</i> : 5 rooms)						*
- 1 room or less	<i>n.s.</i>	<i>ex</i>	<i>ex</i>		<i>ex</i>	<i>n.s.</i>
- 2 rooms or less	***	***	***			<i>n.s.</i>
- 3 rooms or less	***	<i>ex</i>	*			
- 4 rooms or less	***	***	**			
- 6 rooms or more	.	*	<i>ex</i>			
Number of bathrooms ( <i>ref</i> : 1 bathroom)						
- 2 bathrooms and more	***	***	***	<i>ref.</i>	<i>ref.</i>	**
Number of parking lots ( <i>ref</i> : no parking lot)				*		**
- 1 parking lot and more	**	***	***	*	<i>ex</i>	<i>ex</i>
- 2 parking lots and more	***	<i>ex</i>	***	<i>n.s.</i>	<i>ex</i>	<i>ex</i>
Terrace	<i>ex</i>	<i>ex</i>	***	***	***	*
Balcony	<i>ex</i>	<i>n.s.</i>	.			
Elevator	<i>n.s.</i>	<i>n.s.</i>	<i>n.s.</i>			
Swimming pool	***	***	***			
Basement	***	*	***			
Cellar	<i>ex</i>	.	<i>ex</i>	***	***	***
Annexes	**	***	***	***	**	***
Outbuildings	*	<i>ex</i>	<i>n.s.</i>	***	0.050	0.091
Area of land	***	***	***	***	0.096	0.0067
Distance to market square	***	<i>ex</i>				
Distance to drugstore	.	<i>ex</i>				
Distance to food shop	<i>n.s.</i>	<i>n.s.</i>				
- food shop at less than 250m	*	<i>ex</i>	<i>ex</i>			
Distance to bus stop	<i>n.s.</i>	<i>n.s.</i>				
- bus stop at less than 250m	<i>ex</i>	*	<i>ex</i>			
- bus stop at less than 400m	**	<i>ex</i>				
Distance to park	***	**	***			
- park at less than 500m	**	***	<i>n.s.</i>			
Distance to nursery or primary school	<i>ex</i>	<i>ex</i>				
Distance to high school	<i>ex</i>	<i>ex</i>				
- high school at less than 500m	<i>ex</i>	***	<i>ex</i>			

$\lambda$  (spatial errors coefficient)      \*\*\* 0.096    \*\* 0.050    \*\*\* 0.091  
 $\rho$  (spatial lag coefficient)      \*\*\* 0.0067

Caption : grey cell : irrelevant variable in the considered model ;  
*ex* : variable excluded by a stepwise procedure ;  
*ref* : reference modality ; *n.s.* : non significant ;  
./\*/\*\*/\*\*\* : significant to the threshold of 10%/5%/1%/0.1%.

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France.  
1786 observations near Bordeaux, 1134 near Dunkirk and 810 near Rouen.

Notes : we estimate a linear Box-Cox 3 model with spatial errors near Bordeaux and Dunkirk and a Kelejian-Prucha linear Box-Cox 3 near Rouen. Variables of distance to plants are given in meters in all cases. However, the other distance variables are given in meters near Bordeaux and Dunkirk and in classes near Rouen. Near Bordeaux and Dunkirk, classes have been created ; continuous variables and the one per classes have been kept to control for an additional threshold effect.

**Jurisdictional effects.** Near Bordeaux, since the beginning of the 2000s, numerous inhabitants choose to live further from Bordeaux in houses with greater area of land. Jurisdictions of Saint-Médard-en-Jalles, Martignas-sur-Jalles and Saint-Aubin-de-Médoc are especially prized, particularly by business executives who work for aerospace industry in the neighborhoods.

**Temporal fixed effects.** Near Bordeaux, dwellings are more expensive in 2002 all other things being equal; near Rouen, they are more expensive in 2000 and in 2008. Events that can explain these effects have not been identified.

### 3.2 Implicit price of distance to plants

Table 7 provides the average implicit price of distance to hazardous plants over the study period.

TABLE 7 – Average implicit prices

Variable	Bordeaux	Dunkirk	Rouen
Distance to highly hazardous plants	-	12 €/m	3 €/m
Distance to authorized plants	-	-	21 €/m
Living space	-	502 €/m <sup>2</sup>	953 €/m <sup>2</sup>

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France. 1786 observations near Bordeaux, 1134 near Dunkirk and 810 near Rouen.

Notes : with (BoxCox3), the implicit price equals  $\partial \hat{P} / \partial z_k = \hat{p}_k z_k^{\beta_k - 1} / P^{\beta_p - 1}$ .

Comparing the precise values between the three regions is not relevant, as this comparison would require similar local real estate markets and risk perceptions.

The average implicit price of distance to plants corresponds to the *average over all buyers* of their marginal willingness to pay to go one more meter away from the plants. Note that this value can be biased because there is a taste-based sorting on housing market. For example, more risk averse households have a higher willingness to pay to live far from the plants; they will therefore choose dwellings that are more distant from the plants. As the study area is centered around the plants, even if it is wide enough, the average implicit price of distance to plants may be underestimated.

As shown by Table 7, on average over all the considered buyers, the willingness to pay to go one more meter away from highly dangerous plants is of a few euros near Dunkirk and Rouen. In comparison, on average, the willingness to pay to get one additional square meter is of hundreds of euros. Besides, near Rouen, on average, the willingness to pay to go one more meter away from authorized plants is superior to the one to go one more meter away from highly dangerous plants. This is probably due to the fact that households may more perceive pollutions generated by authorized plants. For example, scrapyards in Grand-Couronne, Moulineaux and Petit-Couronne create sound pollutions; heat production plant in Grand-Couronne creates odor pollutions.

### 3.3 Impact of events that can change risk perception

Let's understand why the events that can change risk perception have no impact on the implicit price of distance to plants.

**Local information releases.** The creation of a local committee for information and consultation during the study period near Dunkirk and Rouen does not modify housing prices. This is partly explain by the low participation of households to these committees.

Information leaflets about risk exposure and prevention measures (for example about emergency plan for households) have no impact either. As we said, very probably some future buyers were not informed. Furthermore, these administrative measures combine information and prevention. Prevention measures can reassure and so balance the impact of risk revelation.

**The AZF accident.** The absence of impact of the AZF accident on housing prices confirms the results of Travers et al. (2009) near Port-Jérôme harbor (Seine-Maritime, France). However, near Rouen, Grande Paroisse Normandy is settled in. This plant has a similar activity to the AZF plant and belongs to the same company, Grande Paroisse (a subsidiary of Total group). Its presence could have raised public awareness of dangers due to industrial activities.

**The 2003 law and the technological disasters insurance system.** The technological disasters insurance system improves the coverage of households; its creation in 2003 should so decrease the implicit price of the distance to plants. This coverage is mandatorily included in home insurance, which is widely purchased in metropolitan France (Calvet and Grislain-Letrémy, 2010). Nevertheless, the coverage provided by this guarantee is limited to the real estate of main home and probably even ignored by households. This ignorance is all the more probable in that the technological disasters premium is included in the home insurance premium and amounts to a few euros per year. Besides, even if households knew the 2003 law, they could have been more aware of other publicized measures implemented by the law.

**The implementation of mandatory information for buyers and tenants.** Since June 1st, 2006, the seller or the landlord has to precise in writing whether his dwelling is located in an area covered by a technological (or natural) risk prevention plan and, if so, he should also mention whether the dwelling has been damaged by a technological (or natural) disaster. As technological risk prevention plans were started after the study period, no such information was released. Therefore we cannot estimate the impact of mandatory information on the implicit price of distance to plants.<sup>16</sup>

## 4 Conclusion

Results show that housing prices decrease with respect to the proximity of hazardous plants near Dunkirk and Rouen, but not near Bordeaux. The effect of hazardous industrial plants on housing prices depends so on the nature of industrial activities, historical links between cities and industries, and local real estate market. Furthermore, results indicate that these price differences are modified neither by local incidents, the AZF accident, information policies, nor by the implementation of the technological disasters insurance system.

These results provide partial answer on the impact of technological risk prevention plans on housing prices. These plans can reveal risk, but results suggest that the impact on housing prices would probably be low.<sup>17</sup> In addition, implementing plans could *increase* housing prices via three mechanisms. First, setting up additional measures of risk reduction by the industrialists could reduce households' exposure and so increase the price of their dwellings.

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16. Only the estimation of the impact of mandatory information on the implicit price of exposure to natural disasters would be possible. Unfortunately, the dwellings near Dunkirk are not exposed to natural risks; near Bordeaux and Rouen, exposure to natural risks does not significantly decrease housing prices (Table 6), but this result is not robust as too few dwellings are exposed to natural risks (29 near Rouen and 69 near Bordeaux).

17. Besides, a plan brings information that will be ineluctably revealed. Thus, in any case, this potential decrease of housing prices would penalize only the current landowners.



Second, the plan could imply an exclusion zone in very exposed areas. Results relative to Z1 area near Rouen suggest that this measure could increase housing prices in these zones (by limiting local housing supply and most of all by protecting these dwellings from new neighbors). Third, expropriations could raise housing prices in exposed areas and even beyond, but given the small number of concerned dwellings, this effect probably would be negligible.

Thus, the net impact of technological risk prevention plans on housing prices could be an increase or a decrease of prices in the vicinity of the hazardous plants. The net impact could also be null, as it is the case for natural risk prevention plans (Deronzier and Terra, 2006). Answering properly this question requires a deep analysis several years after the implementation of several technological risk prevention plans in urban areas.

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## A Appendices : descriptive statistics

TABLE 8 – Descriptive statistics of intrinsic characteristics of the dwellings

Variable	Area	Mean	Standard error	Minimum	Maximum
Price (including tax) au January 1st, 2009	Bordeaux	242 727	98 100	31 887	788 572
	Dunkirk	125 920	42 358	13 399	332 241
	Rouen	146 054	63 802	12 159	570 817
House or apartment	Bordeaux	House : 83%		Apartment : 17%	
	Dunkirk	House : 87%		Apartment : 13%	
	Rouen	House : 72%		Apartment : 28%	
Less than 5 years	Bordeaux	Less than 5 years : 23%		More than 5 years : 77%	
	Dunkirk	Less than 5 years : 3%		More than 5 years : 97%	
	Rouen	Less than 5 years : 22%		More than 5 years : 78%	
State (†)	Bordeaux	Good : 91%	Works to do : 7%	To renovate : 2%	
	Dunkirk	Good : 72%	Works to do : 23%	To renovate : 5%	
	Rouen	Good : 80%	Works to do : 13%	To renovate : 7%	
Living space (◊)	Bordeaux	108	42	19	350
	Dunkirk	96	27	27	300
	Rouen	87	35	30	300
Number of rooms (*)	Bordeaux	4.6	1.5	0	10
	Dunkirk	4.7	1.3	0	13
	Rouen	4.4	1.6	0	11
Number of bathrooms	Bordeaux	1.3	0.5	0	6
	Dunkirk	-	-	-	-
	Rouen	1.2	0.4	0	3
Number of parking lots	Bordeaux	No parking lot : 357 ; 1 parking lot : 1196 ; 2 or more : 233			
	Dunkirk	No parking lot : 1108 ; 1 parking lot : 77 ; 2 or more : 11			
	Rouen	No parking lot : 218 ; 1 parking lot : 407 ; 2 or more : 211			
Presence of terrace, balcony or loggia	Bordeaux	Yes : 19%		No : 81%	
	Dunkirk	Yes : 4%		No : 96%	
	Rouen	Yes : 15%		No : 85%	
Presence of elevator	Bordeaux	Yes : 3%		No : 97%	
	Dunkirk	Yes : 5%		No : 95%	
	Rouen	Yes : 4%		No : 96%	
Presence of swimming pool	Bordeaux	Yes : 12%		No : 88%	
	Dunkirk	Yes : 0%		No : 100%	
	Rouen	Yes : 0%		No : 100%	
Presence of outbuildings	Bordeaux	Yes : 9%		No : 91%	
	Dunkirk	Yes : 13%		No : 87%	
	Rouen	Yes : 15%		No : 85%	
Area of land	Bordeaux	Median : 800			
	Dunkirk	-			
	Rouen	Median : 493			

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France.

2006 observations near Bordeaux, 1301 near Dunkirk and 874 near Rouen.

Notes : (\*) Maid’s rooms are considered with zero room.

(†) For half of observations near Bordeaux, state is not provided.

(◊) The imputed living space for missing values is the average living space over the five closest neighboring dwellings with the same number of rooms.

TABLE 9 – Descriptive statistics of extrinsic characteristics of the dwellings

Variable	Area	Mean	Standard error	Minimum	Maximum
<i>Proximity to shops and public utilities</i>					
Distance to market square	Bordeaux	< 500 m : 24%		≥ 500 m : 76%	
	Dunkirk	< 500 m : 28%		≥ 500 m : 72%	
	Rouen	< 500 m : 21%		≥ 500 m : 79%	
Distance to drugstore	Bordeaux	< 250 m : 21%		≥ 250 m : 79%	
	Dunkirk	< 250 m : 47%		≥ 250 m : 53%	
	Rouen	< 250 m : 25%		≥ 250 m : 75%	
Distance to food shop	Bordeaux	< 250 m : 23%		≥ 250 m : 77%	
	Dunkirk	< 250 m : 69%		≥ 250 m : 31%	
	Rouen	< 250 m : 43%		≥ 250 m : 57%	
Distance to bus stop	Bordeaux	< 250 m : 52%	Between 250 m and 400 m : 22%	≥ 400 m : 26%	
	Dunkirk	< 250 m : 86%	Between 250 m and 400 m : 10%	≥ 400 m : 4%	
	Rouen	< 250 m : 75%	Between 250 m and 400 m : 22%	≥ 400 m : 3%	
Distance to park	Bordeaux	< 500 m : 37%		≥ 500 m : 63%	
	Dunkirk	< 500 m : 72%		≥ 500 m : 28%	
	Rouen	< 500 m : 24%		≥ 500 m : 76%	
Distance to nursery or primary school	Bordeaux	< 500 m : 34%		≥ 500 m : 66%	
	Dunkirk	< 500 m : 92%		≥ 500 m : 8%	
	Rouen	< 500 m : 31%		≥ 500 m : 69%	
Distance to high school	Bordeaux	< 500 m : 14%		≥ 500 m : 86%	
	Dunkirk	< 500 m : 51%		≥ 500 m : 49%	
	Rouen	< 500 m : 26%		≥ 500 m : 74%	
<i>Exposure to industrial risk</i>					
Distance to highly dangerous plants (m)	Bordeaux	4 626	1 922	532	10 379
	Dunkirk	1 680	907	41	4084
	Rouen	1 323	903	64	5 142
Distance to authorized plants (m)	Bordeaux	1 778	1 027	49	5 279
	Dunkirk	1 294	611	188	3 452
	Rouen	892	564	64	2 884
View of industrial plants	Rouen	Yes : 90%		No : 10%	
Location in a land use control area (Z1 or Z2)	Bordeaux	Irrelevant			
	Dunkirk	Outside : 100%			
	Rouen	Z1 : 4% ; Z2 : 3% ; outside : 93%			
Location in the zone of the emergency plan for households	Bordeaux	Yes : 1%		No : 99%	
	Dunkirk	Yes : 28%		No : 72%	
	Rouen	Yes : 77%		No : 23%	
<i>Exposure to other risks or pollutions</i>					
Location in the area of servitude or notification for natural (N) or other (O) risks	Bordeaux	(N) Yes : 3%	(N) No : 97%	(O) Yes : 0%	(O) No : 100%
	Dunkirk	(N) Irrelevant		(O) Yes : 0%	(O) No : 100%
	Rouen	(N) Yes : 3%	(N) No : 97%	(O) Yes : 18%	(O) No : 82%
Location in a residual pollution area	Bordeaux	Irrelevant			
	Dunkirk	Irrelevant			
	Rouen	Yes : 4%		No : 96%	
Sound exposure to a land (L) / air (A) transport facility (★)	Bordeaux	(L) Yes : 2%	(L) No : 98%	(A) Yes : 13%	(A) No : 87%
	Dunkirk	(L) Yes : 37%	(L) No : 63%	(A) Irrelevant	
	Rouen	(L) Yes : 32%	(L) No : 68%	(A) Irrelevant	
Location in environmental protection area	Bordeaux	Yes : 1%		No : 99%	
	Dunkirk	Irrelevant			
	Rouen	Yes : 7%		No : 93%	
Location in conservation easement area	Bordeaux	Yes : 0%		No : 100%	
	Dunkirk	Yes : 3%		No : 97%	
	Rouen	Yes : 37%		No : 63%	

Sources : French solicitors - PERVAL and data collected and standardized by Technical Studies Center of Public Works of Normandy and Centre, Nord and Picardy, and South West France.

2006 observations near Bordeaux, 1301 near Dunkirk and 874 near Rouen.

Notes : (★) A dwelling is considered as exposed to a land transport facility if sound is above 60 dB / to an air transport facility if sound is above 50 dB.