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# How does a change in risk perception affect the housing market - Evidence from an industrial accident in France

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# How does a change in risk perception affect the housing market ? Evidence from an industrial accident in France

(preliminary title)

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## Abstract

Industrial risk is among the many neighborhood characteristics one has to consider when facing housing choices. Because of endogeneity issues, it is difficult to disentangle the causal impact of risk perception on housing market characteristics. This paper uses a massive industrial accident as a natural experiment in which risk perception was shifted. Based on a difference-in-difference matching strategy, it shows that although transaction prices do not change as a result of this shift, local housing markets are indeed affected. In particular, the vacancy rate increases, and the standard of living tends to deteriorate in the at-risk areas. It thus shows that industrial risk can lead to residential sorting.

Keywords : industrial risk, housing market, propensity score matching, natural experiment.

JEL classification : R20, R21, R23, C21.

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## Introduction

Manufacturing activities account for a substantial share of developed countries economies. In 2012 in France, about 12% of total employment and 25% of GDP came from manufacturing. Moreover, sectors such as electricity production or waste management are likely to grow in the coming decades, due to population growth. On the one hand, such industries provide employment and contribute to local and global growth and wealth. On the other hand, they can present nuisances and pose a threat to local populations. Industrial accidents are the most spectacular realizations of such risks. They are relatively rare but can lead to substantial human and material damage. To which extent do individuals take this risk into account and how does it affect the local markets? In particular, this paper relies on an empirical strategy to better understand of the consequences of industrial risk perception on the housing markets and local neighborhood characteristics.

Most empirical studies on industrial risk are based on preference revelation through the housing market. This hedonic approach is in particular summarized by Davis (2011). It provides a way to measure taste or distaste for a given characteristic through its particular impact on housing prices. If technological risks are considered a negative amenity, then all other things being equal, housing prices in exposed neighborhoods should be lower. Empirically identifying this relation has yet proven to be complex. Indeed, the location of dangerous plants can hardly be thought of as random since the decision is often highly political and new plants tend to be constructed in neighborhoods with *ex ante* housing prices lower than average and very specific socio-demographic characteristics (Davis, 2011).

Two identification strategies can be found in the literature. The first one relies on panel data analysis. Davis (2011) uses this approach in his study of neighborhood change after new plants openings. It effectively controls for neighborhood and time fixed-effects, but does not guarantee that the relationship of interest is fully exogenous. The second approach relies on quasi-experiments in which a sudden unforeseen change modifies local amenities. A frequently analyzed setting is the American *Superfund*, a federal program aiming at cleaning polluted sites (see for example Viscusi and Hamilton (1999); Kiel and Williams (2007); Greenstone and Gallagher (2008)). Another example is provided by legal

changes in pollution control, such as the *Clean Air Acts* passed in the USA in the 1970's. (see for example Chay and Greenstone (2005); Greenstone (2002)). These contributions tend to show that the housing price-elasticity with respect to environmental quality is relatively low.

In both these settings, the identification can be questioned. In the first case, only a few of the potentially eligible sites could benefit from *Superfund*. The authors argue that this restriction could not be anticipated for those close to the threshold and resort to a regression discontinuity design. This strategy allows them to identify the effect close to the threshold but yields external validity concerns. In the second case, the exogeneity of new environmental laws can clearly be questioned, especially in the USA where lobbying is known to have a significant impact on political decisions.

Moreover, housing markets are not standard, and attempts at modeling and predicting housing prices often lead to the conclusion that it is not an efficient market. For example, Case and Shiller (1989) show that on the one hand, there is an important time persistence of real housing prices, and on the other hand, real interest rates do seem to be incorporated in prices. These counter-intuitive results can at least partially be explained by the specificities of the housing market such as high transaction costs or tax considerations. They are also consistent with behaviors induced by the “disposition effect” that can be observed in finance. Shefrin and Statman (1985) model this tendency to “sell winners too early and ride losers too long” even when the contrary would be more efficient and attribute it to loss aversion, but it has also been observed in the housing market. For example, Genesove and Mayer (2001) analyse the Boston housing market in the 1990s and find evidence of nominal loss aversion among sellers. Such time dependence in prices and loss aversion further complicates the relationship between risk perception and housing prices, and prices alone may not be able to accurately reflect the neighborhood changes that occur when risk or risk perception shifts in a given area.

This paper contributes to the existing literature in three ways. First, its identification strategy relies on a very convincing and yet very little studied quasi-experiment provided by the AZF accident that occurred in 2001 in Toulouse (France). To my knowledge,

only one previous publication partially uses this particular setting. Grislain-Letrémy and Katosky (2013) adopt a hedonic approach to industrial risk and housing prices in three French cities. It is consistent with previous literature and tends to indicate that industrial risk is not a first order parameter in determining housing prices. More importantly, it does not find a difference before and after the AZF accident.

Second, this paper relies on high-quality administrative data that can yield detailed information about neighborhood characteristics. Although the results confirm that there is no apparent impact of the accident on price, other characteristics of the at-risk neighborhoods can be studied and show that neighborhoods are affected by the change in risk perception. In particular, the vacancy rate of at-risk neighborhoods significantly increases, overcrowding increases and earnings decrease. This suggests that although average transaction prices do not change, the at-risk housing markets do change after the risk perception is changed by the accident.

Third, I adopt a difference-in-difference matching empirical strategy that is relatively rare in this field and can overcome some of the computational challenges of more traditional hedonic approaches.

The following sections first present the empirical strategy, then the data sources and descriptive statistics and finally the main results.

## **1 Empirical strategy**

### **1.1 A natural experiment**

In September 2001, the chemical plant AZF exploded in Toulouse (South of France). The plant itself was highly damaged, and other consequences for the city were both extremely strong and unexpected. The accident amounted to the explosion of 20 to 40 tons of TNT and could be felt as far as 75 km away from the site. Material damage such as broken windows occurred up to 7 km from it and many amenities were destroyed. Among them, about a hundred schools and more than 25500 housing units were damaged. More than 2400 people were hospitalized and 33 were killed in the explosion.

The dangerousness of the plant was known to be high, but the extent of the consequences was much higher than what was considered possible in accident scenarios. The gap was such that at first the accident was thought to be a terrorist attack, and reported as such in local and national press. It is now considered as the worst technological accident in France since the Second World War. At the time of the accident, the event and its local consequences were widely covered in the media. Combined with the extreme rarity of such events, it can reasonably lead to the assumption that risk perception changed in France after September 2001.

This strong, unexpected national shock in risk perception can thus be used to identify the effect of an increase in risk perception on other at-risk areas in France.

## 1.2 Identification problem

Assessing the impact of the AZF accident can be thought of in the econometric framework developed for public policy evaluation. The Rubin model (Rubin, 1974) has become the standard guideline for such questions, and it is useful to recall its main features.

I denote  $Y_i^1$  the outcome of a treated location,  $Y_i^0$  the outcome of the same location in the absence of treatment, and  $T$  the treatment dummy. In our case, a location will be considered treated if it is close to a dangerous plant. The parameter of interest is the average difference between the two potential outcomes for treated units, known as the *average treatment effect on the treated* :  $ATT = \mathbb{E} [Y_i^1 - Y_i^0 | T_i = 1]$ . By definition, one cannot observe both  $Y_i^1$  and  $Y_i^0$ , that is what happened after the accident and what would have happened in its absence. This “fundamental problem of causal inference” has led to different empirical strategies in the literature. They all resort to non-treated units to estimate a convincing counterfactual outcome.

The construction of the counterfactual is critical for the credibility of the results obtained from quasi-experimental settings. In particular, the implantation of dangerous plants is likely not to be random, thus a direct comparison of outcomes between at-risk areas and other areas would lead to biased estimates.

### 1.3 Matching difference-in-difference strategy

A natural approach would be to rely on a difference-in-difference strategy, comparing at-risk areas with control areas both before and after the accident. The ATT is then estimated as follows :  $\widehat{ATT} = \frac{1}{n_1} \sum_{i \in I_1} [Y_{it'}^{T=1} - Y_{it}^{T=1}] - \frac{1}{n_0} \sum_{i \in I_0} [Y_{it'}^{T=0} - Y_{it}^{T=0}]$ , where  $t$  and  $t'$  denote respectively the before and after periods,  $I_1$  and  $I_0$  the set of treated (respectively control) locations, and  $n_1$  and  $n_0$  the number of locations in  $I_1$  (respectively  $I_0$ ). This strategy relies on the assumption that if the accident had not happened, the outcome in the treated and control groups would have followed the same trend. Whether this “common trend assumption” holds can only be checked before the accident. It is likely to be rejected if the areas subject to industrial risk have different economic trends than control areas.

Matching methods can then provide a solution as they rely on pairing each treated unit with *ax ante* similar non-treated units. This approach can be combined with difference-in-difference and the ATT is then estimated by comparing the outcomes of each pair. Initially, matching estimation relied on finding pairs of observation having exactly the same *ex ante* observable characteristics. The main caveat of this approach is that one wants to include as many characteristics as possible in the matching process, but doing so reduces the chances of finding a twin observation for each treated one. Rosenbaum and Rubin (1983) show that this “curse of dimensionality” can be resolved, as it is equivalent to condition the outcomes on observable characteristics or on propensity score based on these characteristics. I adopt this now standard strategy in my analysis.

Following Smith and Todd (2005), our difference-in-difference matching estimator can be written as follows :

$$\widehat{ATT} = \frac{1}{n_1} \sum_{i \in I_1 \cap S_p} \left[ (Y_{it'}^{T=1} - Y_{it}^{T=1}) - \sum_{j \in I_0} w(i, j) (Y_{it'}^{T=0} - Y_{it}^{T=0}) \right]$$

where  $S_p$  is the support of the propensity score  $p$ ,  $n_1$  the number of locations in  $I_1 \cap S_p$ . The weights  $w(i, j)$  depend on both the distance between  $p_i$  and  $p_j$  (the propensity score estimates for locations  $i$  and  $j$ ), and the chosen estimation method (I use a kernel method).

## 2 Data sources and descriptive statistics of the panel

### 2.1 Housing and sales data

Data quality is one of the main assets of this paper. Among them are an exhaustive administrative database on housing in France (Filocom), and data collected at the local level on real estate transactions (Perval).

The Filocom database was created by the French tax administration using four different tax files on both housing and households. As a result, this database includes households characteristics (including age, earnings, eligibility for certain tax deductions, family structure), housing characteristics (date of construction, square footage, number of rooms and several quality measures) and landlords characteristics for all 30 million housing units in France. The finest geographic scale that can be used to locate housing units are cadastral plan sections, which amount roughly to a block. These sections contain on average more than 200 housing units but this measure can vary greatly. It is much higher in urban areas and in particular in the Paris region where housing is much denser than in other parts of France.

This database can provide precise and detailed insight as to the structure and characteristics of a neighborhood, but it cannot account for housing prices. To study the impact of the accident on real estate prices, I thus use the Perval notaries database as an alternative source. Short of tax files, it is the most comprehensive source on real estate transactions in France. This data is collected from notaries' offices and contains mostly information on the estate being sold, along with partial characteristics of sellers and buyers. Cadastral plan units are again the most precise geographic unit that can be used to assess the location of the estates.

In this paper, I mostly use two years of data: 2000 and 2002, a year before and a year after the accident. The year 1998 is also used to better assess the resemblance between treated and control areas before the accident. Filocom was constructed using tax files, which means that it follows the same structure. For each year, household information concerns the previous year, whereas housing information is set on January 1<sup>st</sup> of the



given year. For example, the 2001 file contains households earnings in 2000 and housing specificities on January 1<sup>st</sup> 2001. In the remaining of the paper, I will refer to 2000 as the year of reference for both these categories of data and proceed in a similar way for 2002.

The data does not initially include the cadastral plan sections coordinates. I thus recovered this information from the cadastral plan, matching each section with its centroid coordinates. Unfortunately, cadastral plan historical data does not exist. I extrapolated the sections' coordinates based on today's cadastral plan and was not able to recover all past coordinates. The sample size remains unusually large, given that over 198000 sections present both in 2000 and in 2002 were successfully matched with their coordinates.

## 2.2 Defining treatment and control locations

The location of dangerous plants is considered as public information, thus a government website<sup>1</sup> provides the complete list along with some information about each plant. The European Council "Seveso Directive" defines two levels of risk, depending on the potential damage that could occur and the estimated probability of such an occurrence. In this paper the analysis is focused on plants with the highest level of risk.

There are 613 such plants in France nowadays, and I associated each Filocom and Perval geographic section to its closest dangerous plant. Only 496 plants are associated with the main data in this way, for two reasons. First, some plants were too close to one another to be able to distinguish their coordinates and they are thus considered as one unit. Second, as I was not able to recover the coordinates of all cadastral plan sections, it is possible that some neighborhoods should be absent from the sample.

A given section is considered as treated if its centroid is within two kilometers of a dangerous plant. This definition is restrictive enough to reasonably expect risk perception in the area to be high, and wide enough to ensure that there are indeed inhabited section within this range. I identify 4,881 such treated sections.

Control areas are defined in a similar way: a control section should not be too close to a dangerous plant (at least 7 kilometers away). Recall that the AZF accident caused

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<sup>1</sup><http://www.installationsclassees.developpement-durable.gouv.fr>

damage on housing up to seven kilometers away from the plant so it is plausible that there should be some impact on risk perception in areas that are less than seven kilometers away from a given dangerous plant. In addition, we want to ensure that the unobserved characteristics of treated and control areas do not differ too much, in particular the local amenities available to local populations. We thus restrict control areas not to be further than 10 kilometer away from dangerous plant. This restriction does not jeopardize the power of the estimation as there are 19,351 such sections.

### 2.3 Descriptive statistics

The table 1 provides some insight as to the differences between treated and control sections before the AZF accident (columns 1 to 3). Treated locations are on average much bigger than control areas and have a slightly different household composition. Indeed, the household size is higher, but the number of consumption units (that takes into account the household structure in terms of adults and children) is similar. This difference in household composition is confirmed by the average number of children under 18 or 6 years old, which are both higher in treated areas. Overcrowding and severe overcrowding are two housing quality measures defined by the French housing agency<sup>2</sup>. A given housing unit is considered overcrowded if there are less than 16 m<sup>2</sup> of living area for the first resident and less than 11 m<sup>2</sup> for each other resident. Severe overcrowding occurs when there is less than 9 m<sup>2</sup> per person. Both these measures are significantly lower in treated areas before the accident. Household earnings seem slightly higher in at-risk areas, whether in total or per consumption unit. There is thus little evidence supporting *ex ante* standard of living differences. The share of housing units occupied by their own landlords is significantly higher and the selling rate is lower in control areas.

This suggests that even before the AZF accident, housing strategies are different in at-risk and control areas, which confirms that a direct comparison of treated and control areas cannot provide a causal estimation of the impact of risk perception. Moreover, figure

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<sup>2</sup>ANAH (Agence Nationale de l'Habitat)

Table 1: Descriptive statistics

Variables	Control	Treated	Diff.	All	Price subsample	Diff.
	(1)	(2)	(1) - (2)	(1) $\cup$ (2)	(1) $\cup$ (2)	(4) - (5)
Nb. Households	221	258	-36***	229	297	-106**
Mobility rate	19.46%	21.55%	-2.09***	19.88%	21.8%	-0.03***
Construction rate	3.19%	3.12%	0.08	3.18%	3.33%	0.00***
Destruction rate	0.86%	1.08%	-0.22***	0.91%	0.79%	0.00***
Vacant	7.40%	8.01%	-0.61***	7.52%	6.67%	0.01***
Principal housing	85.48%	88.79%	-3.31***	86.15%	87.83%	-0.03***
Secondary housing	6.82%	2.97%	3.85***	6.04%	5.22%	0.01***
Furnished housing	0.30%	0.23%	0.07*	0.29%	0.28%	0.00
Transaction rate	1.98%	2.32%	-0.34***	2.05%	4.12%	-0.03***
Nb. Transactions	2.27	4.05	-1.78***	2.63	6.87	-6.59***
Household size	2.63	2.60	0.02***	2.62	2.55	0.11***
Household size (consumption units)	1.73	1.72	0.01***	1.73	1.69	0.06***
Overcrowding	4.63%	4.60%	0.02	4.62%	4.25%	0.01***
Severe overcrowding	2.77%	2.63%	0.14	2.74%	2.80%	0.00
Nb. of children < 18 y.o.	0.58	0.59	0.00	0.58	0.57	0.02***
Nb. of children < 6 y.o.	0.19	0.19	0.00	0.19	0.19	0.01***
Household earnings	23702	20222	3480*	23001	21471	2376*
Household earnings per c.u.	13597	11694	1903**	13214	12446	1192*
Live-in landlord	71.18%	62.47%	8.71***	69.43%	67.44%	0.03***
Rented	17.5%	20.27%	-2.77***	18.06%	19.57%	-0.02***
Rented social housing	5.95%	12.5%	-6.54***	7.27%	9.20%	-0.03***
Nb. Obs.	19351	4881	-	24232	8629	-

Source : Filocom, Perval. Author's calculations.

Note : The price panel is a subset of observations for which transactions occurred both before and after the accident, a necessary condition to study its impact on transaction prices.

Reading : \*\*\* : significant at the 1% level; \*\*: significant at the 5% level; \*: significant at the 10% level.

2.3 shows that the common trend assumption is not reliable for many outcomes before the accident.

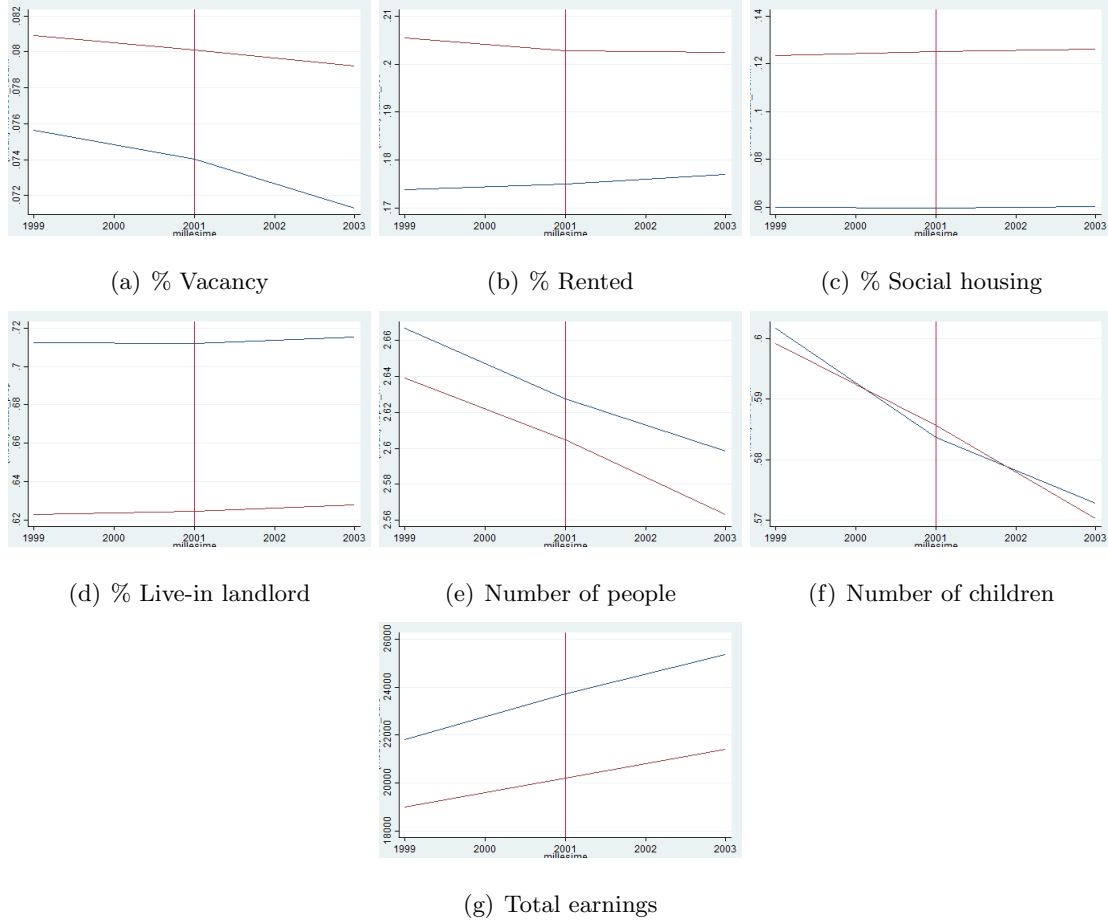


Figure 1: Outcome trends

Table 1 also shows how this main panel differs from the subset of observations that can be used to study the effect of the accident on transaction prices (columns 4 to 6). Only the areas where transaction occurred both before and after the accident can be included in this subset. The column 6 of the table shows that for all the above characteristics, the price subsample is significantly different from the main panel. This finding requires further analysis to understand better what kind of selection occurs between the two panels.

### 3 Findings and discussion

Tables 2, 3, 4 and 5 show the main estimation results. To obtain these matching estimations, a first step lies in the propensity score estimation. It is estimated using locations characteristics before the AZF accident. The propensity score is estimated separately for the main panel and the price subsample with a probit model. It includes five categories of variables:

1. *ex ante* cadastral plan section characteristics: the number of households, share of collective housing, share of rented housing units, of social housing, of vacant housing units, share of main or secondary residence, number of sales in 2000, share of overcrowded or severely overcrowded housing units;
2. *ex ante* housing characteristics: average living area and number of rooms, average date of construction, a seven-position quality measure;
3. *ex ante* household characteristics: number of persons, number of consumption units, number of children under 18 and 6 y.o., share of households eligible to tax deductions;
4. *ex ante* trends for these variables when available;
5. cadastral plan section time-fixed characteristics.

The predicted treatment probability are then used in the matching estimation to assess the proximity between two observations.

I mentioned earlier the specificity of the price panel used to assess the impact of the accident on prices and other transaction outcomes. The results of table 2 should thus be considered with caution, but they tend to confirm previous results. Indeed, there does not seem to be any significant difference of evolution between treated and control group in the price of transactions. However, table 3 shows that although the average number of sales does not change, the selling does appear to increase in the at-risk areas compared to the control areas.

This is consistent with the disposition effect theory, especially since table 4 shows that the vacancy rate significantly increase, if only by 0.02 percentage points. There might

Table 2: Matching estimation – sales characteristics

	Matching estimator	Standard error
Price (€)	-6952*	3654
Price per square meter (€/m <sup>2</sup> )	-26.64	34.443
Living area (m <sup>2</sup> )	-2.446	2.885

Source : Filocom, Perval. Author’s calculations.

Sample : treated and control cadastral plan sections.

Note : The results are obtained through propensity score kernel matching with optimal bandwidth.

Reading : \*\*\* : significant at the 1% level; \*\*: significant at the 5% level; \*: significant at the 10% level.

Table 3: Matching estimation - housing stock

	Matching estimator	Standard error
Mobility rate (pp)	0.047	0.335
Construction rate (pp)	0.009	0.275
Destruction rate (pp)	-0.097	0.094
Number of transactions	0.075	0.101
Selling rate (pp)	0.202*	0.135

Source : Filocom, Perval. Author’s calculations.

Sample : treated and control cadastral plan sections (all housing units).

Note : The results are obtained through propensity score kernel matching with optimal bandwidth.

Reading : \*\*\* : significant at the 1% level; \*\*: significant at the 5% level; \*: significant at the 10% level.

also be a sorting process at stake in the at-risk areas, more housing units being put on the selling market but only the “best” being sold, the others remaining vacant for a longer period. This process could explain the absence of price change, the increased rate of transactions and the higher vacancy rate.

The main results of interest concern the average household characteristics in the at-risk areas, shown in table 5. These results only come from housing units that are neither vacant or furnished and are a declared as principle housing. Firstly, households compo-

Table 4: Matching estimation – housing status

	Matching estimator	Standard error
Vacancy rate (pp)	0.216*	0.120
Principal housing (pp)	-0.143	0.125
Secondary housing (pp)	-0.064	0.066
Furnished housing (pp)	-0.009	0.021

Source : Filocom, Perval. Author's calculations.

Sample : treated and control cadastral plan sections (all types of housing units).

Note : The results are obtained through propensity score kernel matching with optimal bandwidth.

Reading : \*\*\* : significant at the 1% level; \*\*: significant at the 5% level; \*: significant at the 10% level.

Table 5: Matching estimation – household characteristics

	Matching estimator	Standard error
Household size	-0.010***	0.003
Household size (consumption units)	0.000	0.001
Overcrowding (pp)	0.033***	0.008
Severe overcrowding (pp)	0.028***	0.008
Living area (m <sup>2</sup> )	-0.408***	0.039
Number of children < 18 y.o.	-0.004***	0.002
Number of children < 6 y.o.	-0.004***	0.001
Household earnings (€)	-1,646***	213
Household earnings per cons. unit (€)	-76*	55
Live-in landlord (pp)	0.015	0.017
Rented (pp)	-0.006	0.010
Rented social housing (pp)	-0.001	0.001

Source : Filocom, Perval. Author's calculations.

Sample : treated and control cadastral plan sections (principal housing only).

Note : The results are obtained through propensity score kernel matching with optimal bandwidth.

Reading : \*\*\* : significant at the 1% level; \*\*: significant at the 5% level; \*: significant at the 10% level.

sition changes more there than in control areas : although the household size is slightly lower, the number of consumption units does not change. Moreover, the average number children under 18 or 6 years old declines. Secondly, household earnings decrease significantly compared to the control areas, both in absolute terms and relative to the number of consumption units in the household. Thirdly, over-crowding and severe over-crowding increase in at-risk areas. These last two results seems to indicate a socio-economic change in the at-risk areas.



## Conclusion

This paper contributes to the literature on the link between industrial risk and housing markets. The quasi-experimental setting provided by the AZF accident guarantees that this paper's results are not driven by other evolutions. It is consistent with previous results that find little evidence supporting the impact of such risk on housing prices. However, at-risk neighborhoods do react to industrial risk perception in other ways. Households living in a dangerous area after a shift in risk perception tend to be poorer, less often have young children and live in smaller housing units. Additionally, the vacancy rate in these neighborhoods increases, suggesting a less attractive housing market.

Hedonic analysis of environmental goods relies on the assumption that a taste or dis-taste for a given characteristic should automatically translate into an upward or downward shift in housing prices. This paper provides evidence that this is not necessarily the case and that the absence of a relation with price can hide more complex mechanism on the housing markets.

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