

Tonin, Stefania; Turvani, Margherita

**Conference Paper**

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50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Tonin, Stefania; Turvani, Margherita (2010) : Environmental contamination and industrial real estate market: an application of hedonic price method in Italy, 50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden, European Regional Science Association (ERSA), Louvain-la-Neuve

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# **Environmental contamination and industrial real estate market: an application of hedonic price method in Italy**

By

Stefania Tonin (University IUAV of Venice)  
Margherita Turvani (University IUAV of Venice)

## **Abstract**

This paper investigates the effect of contamination and remediation on industrial and commercial real estate property market in the Italian NPL site of Porto Marghera, Venice, using hedonic price method and spatial econometrics to capture the spatial dependence between neighbouring properties.

Results show that increasing distance from previously contaminated sites where permanent safety measures have been implemented has a positive effect on prices of nearby properties, suggesting the existence of post-cleanup stigma for this type of action. On the other hand, we find that a complete environmental remediation has a positive and significant effect on property price. The findings suggest that more enduring solutions have a positive effect on real estate properties.

We also investigate the effect of the main properties' characteristics, such as size, age, location and economic factors on sale prices and our results support the findings of the main economic literature. Finally, we estimate a spatial lag model demonstrating the existence of spatial autocorrelation in property prices.

**Keywords:** industrial and commercial property, hedonic price model, contaminated site, spatial dependence

## **1. Introduction and Motivation<sup>1</sup>**

In this paper we use hedonic analysis to study the effects of contamination, environmental remediation and proximity to already cleaned up sites on the value of industrial and commercial properties localized within the boundaries of one of the largest and most contaminated site in Italy, Porto Marghera, in the Lagoon of Venice, few kilometres from Venice' historical centre.

There are numerous economic studies that have measured the effect of contamination on the value of residential properties (see, for example, de Vora et al. 2009; Deaton and Hoehn, 2004; Roddewig,

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<sup>1</sup> This research was supported by funding from CO.RI.LA

1996, 1999, and Hirshfeld et al., 1992), but very few have been conducted on the effects of contamination on the value of commercial and industrial properties.

This work is the first attempt in Italy to estimate the impact of these effects and it contributes to the very limited applications of Hedonic Price Method (HPM) to study the Italian real estate market. Data on real estate transactions in general and on industrial and commercial properties specifically are difficult to collect. In Italy, the electronic registry of these real estate operations is virtually not existent; in the case of industrial and commercial properties furthermore the limited frequency of transactions and consistence of the overall market need to be accounted for. It has been argued (Jackson, 2001) that the lack of more systematic research on the functioning of this specific section of real estate market may be due to the infrequency of transactions involving contaminated or previously contaminated properties and to the high heterogeneity of such properties as compared to single-family houses.

This paper utilizes information coming from three different sources: the local cadastral register for information on industrial and commercial properties that have been exchanged in the period 1997-2008; the Venice Register of deeds for information regarding the economic value of those transactions; the Veneto Region database collecting information on soil contamination and cleanup interventions. Our original sample collects 187 industrial and commercial real property deeds in the NPL site of Porto Marghera, Venice. All data are georeferenced using Arcgis.

Hedonic price model (HPM) is an economic valuation technique commonly defined as “indirect” valuation or revealed preference method. This technique relies on observable market transactions to obtain values for different characteristics of the goods. Based on the results of the main economic literature, we select the main variables to include in our HPM models. We specifically consider the embodied characteristics of the property (size, age, etc.), location variable, and economic indicators. Moreover, the role of variables describing the environmental status of the industrial and commercial properties sold is explicitly investigated.

The purposes of this paper are twofold. First, we apply hedonic price method for estimating the effects of the main property characteristics on the value of industrial and commercial real estate property. In particular, we are interested to measure both the effect of a complete environmental remediation on the sale price of real estate property transactions and the effect of a partial environmental remediation on the price of nearby properties. Second, we want to use a spatial lag model to account for possible spatial dependency between observations at different locations. In traditional real estate economics, hedonic price models do not properly consider the spatial dimension of property prices, even though

models include characteristics that vary spatially, e.g., the distance to an undesirable land use or disamenity.

Results suggest that proximity to previously contaminated sites where permanent safety measures have been implemented has a negative effect on prices of nearby properties, whereas complete environmental remediation has a positive and significant effect on property sale price. Possibly a stigma effect seems to apply selectively to this market because buyers are uncertain on future environmental liability when complete cleanups are not accomplished.

Finally, results show the existence of spatial dependence, meaning that the prices and the characteristics of real estate properties that are nearby are more similar than those of the properties that are farther apart (Anselin et al., 2008).

The remainder of this paper is structured as follows. The next Section discusses the main concepts and provides a brief literature review of applications of hedonic price models in the context of contaminated sites. Case study and data used in this analysis are described in Section 3 and Section 4. Section 5 and Section 6 present and discuss the econometric model and its results. An application of a spatial lag model is proposed and discussed in Section 7, and Section 8 concludes.

## **2. Key Concepts and Previous Literature**

“Property is an example of what in economics is termed a differentiated good. Such goods consist of a diversity of products that, while differing in a variety of characteristics, are so closely related in consumers’ minds that they are considered as being one commodity” (Day, 2001). The economic valuation of this kind of goods is better performed through approaches aimed to impute prices of attributes based on the relationship between the observed prices of differentiated products and the number of attributes associated with these products. One of the most powerful valuation techniques able to capture the implicit price of the relevant attributes is called Hedonic Price Model (HPM).

Hedonic price model is a revealed preference method of estimating the value and the demand for goods. It is a revealed preference method because preferences are inferred from actual, observed, market-based information.

The theoretical foundation of HPM comes from the work of Lancaster (1966), who stated that a commodity can be decomposed into a bundle of attributes, and Rosen (1974) who gave the correct interpretation of the hedonic functions<sup>2</sup>.

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<sup>2</sup> Colwell and Dilmore (1999) prove that the first hedonic analysis was implemented by Haas in 1922. Later, in 1926 Wallace used regression analysis, and used characteristics such as the productivity of the land, its crop allocation, and the

The HPM has been implemented in different field of application<sup>3</sup> and in the last decades has found wide application in environmental economics literature, due to the necessity to assign a monetary value to environmental goods and services lacking a proper market price. For example, many scholars have used the hedonic approach to estimate the effect of environmental quality on house prices. It is the case of the relationship between house price and air pollution (see e.g. Bayer et al., 2009; Murty and Gulati, 2005; Banzhaf, 2005; Beron et al., 2001; Chattopadhyay, 1999; Kiel and McClain, 1995; Smith and Huang, 1995), between house prices and open space or environmental amenities (see e.g. Sander et al, 2009; Anderson et al., 2006; Morancho, 2003; Bastian et al., 2002; Geoghegan, 2002; Correll, 1978); between house prices and noise and visual intrusion (Kim et al., 2007; Lake et al., 1998); or water quality (see e.g. Leggett, 2000; Hoehn et al., 1987), or hazardous waste and landfill (see e.g. Hibiki and Managi, 2006; Hite et al., 2001; Kohlhase, 1991; Nelson et al., 1992).

Of course, hedonic analysis has also been used to study the housing market more generally (Sheppard 1999; Malpezzi 2002; Chin et al. 2003; and Palmquist 2005).

#### *Hedonics and contaminated site*

The hedonic pricing method has been applied in numerous studies to determine the influence of environmental contamination on the value of residential properties located in the proximity of contaminated sites (see, for example, de Vora et al. 2009; Deaton and Hoehn, 2004; Roddewig, 1996, 1999, and Hirshfeld et al., 1992). Several studies (Ketkar 1992; Kiel and McClain 1995; Kohlhase 1991; Smith and Desvousges 1986; and Thayer et al., 1992) found that proximity to a hazardous site reduces housing prices depending on distance from that site.

Other papers have estimated the existence and duration of contamination stigma<sup>4</sup> (McCluskey and Rausser, 1999; Bond 2000; Bible et al. 2002) while Kiel and Zabel (2001) calculated the appreciation in housing values associated with cleaning up a Superfund site in Woburn, Massachusetts, and use it to approximate the total benefits from cleanup.

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distance to the nearest town to explain the value of farmland in Iowa. According to Coulson (2008), Court (1939) is generally regarded as the founding father of hedonic analysis, in part because he was the first to use the term “hedonic” in describing his methods.

<sup>3</sup> Hedonic price analyses have been applied to many different products such as mobile phone (Dewenter et al., 2007); automobiles (Court, 1939; Griliches, 1961; Berry et al., 1995, 2003), wine (Nerlove, 1995), modern technology products such as personal computers (Griliches, 1994; Pakes, 2003) and internet (Lee et al., 2003) and even landscape quality, piece and quiet, and islands (Tangerini and Soguel, 2006; Day et al., 2003; Bonnetain, 2003) or the benefit of public project (Kanemoto, 1988).

<sup>4</sup> Guntermann (1995) states: “Stigma may be referred to as the loss in value of a contaminated property that cannot be directly attributed to remediation or indemnification costs or risks, i.e., it is a loss in value because of unspecified greater perceived risk associated with a property”.

Vice versa, few attempts to model the price of commercial and industrial properties in a hedonic framework can be found, and even fewer studies exist that have looked at the effect of environmental contamination on industrial and commercial property values. The application of this technique to commercial and industrial properties is limited by the difficulty of assembling a sufficiently large number of transactions on relatively homogeneous properties.

Guntermann (1995) explores the impact that open and closed sanitary landfills have on surrounding industrial land values using 153 transactions of industrially zoned land in Phoenix, Arizona over 1984 to 1994. The results of this research indicate that an open solid waste landfill adversely affects the value of surrounding industrial land. There is no evidence that closed solid waste landfills adversely affect land values.

McGrath (2000) investigates the role of contamination risk in industrial redevelopment decision in the city of Chicago. He analyzes 195 industrial properties sold in Chicago from August 1983 to November 1993. The results of this study support the conclusion that contamination risk reduces the value of land, which in the short term reduces the value differential available to an investor and increases the scale of financial capital required for redevelopment. But evidence suggests that investors could expect to recoup the expenditures required to remove contamination liability through the increase in land value after remediation.

Jackson (2002) examines the effects of environmental contamination on the sale prices of industrial properties using sales in Southern California from 1995 to 1999. The final database includes contaminated properties and un-contaminated properties comparable on the basis of location, age and size. Industrial properties with un-remediated contamination transact at prices approximately 30 percent less than unimpaired properties, but are undistinguishable after cleanup from comparable uncontaminated properties. Furthermore, this study provides strong statistical evidence of the temporary nature of stigma effect for contaminated industrial real estate.

Howland (2002) investigates the circumstances when the cost of cleanup is high enough, relative to land values, that the government has to provide subsidies, and to what extent contamination deters inner city revitalization. These questions are addressed by tracking all sales, the selling price, the length of time on the market and the presence of contamination in an industrial area in southwest of Baltimore. Out of 740 parcels for industrial use, over the period of 10 years, 161 went on market and contaminated properties were sold without any government intervention, while the market adjusted to contamination by lowering prices.

Schoenbaum (2002) investigates the effects of perceived or real environmental contamination on land value and on the economic redevelopment in a heavily industrialized area of Baltimore, Maryland. She collects a time series dataset of all non residential parcels between 1963–1999. She concludes that environmental contamination alone is not a significant constraint to real estate transactions. In particular, results do not show any systematic relationships between pollution, on the one hand, and land prices, vacant or underused properties.

Ihlanfeldt and Taylor (2004) investigate the potential effects of hazardous waste sites (HWS) on commercial and industrial property values in Fulton County, Georgia which are more likely to be located near hazardous waste sites as compared to residential properties, and to incur loss in value. They indeed find that industrial and commercial properties located in proximity of HWS experience reduction in property value, large enough to justify private cost-sharing and tax increment financing as possible funding mechanisms for cleanup.

Longo and Alberini (2006) investigate how the presence of contamination and its perception influence the value of commercial and industrial properties in Baltimore City. They collect arms-length sales occurred in the period 1990-2000 with the aim of determining if the value of these properties is influenced by the proximity to contaminated sites, listed on public registries of known or suspect contamination. They implement separate analysis for commercial and industrial properties finding that industrial property prices do not suffer any externality by the proximity to listed or de-listed contaminated sites, while commercial properties prices are positively related to proximity to these sites. In particular, the estimated coefficient for listed sites is larger than the coefficient for de-listed sites.

The existing literature on the effect of contamination on industrial/commercial properties does not reach a consensual conclusion. Industrial real estate market and the formation of price behave differently according to specific contexts and investors' interests. In some cases real estate developers or private business may still find profitable to buy a contaminated land in one specific location if their activities can absorb the risks of purchasing, cleaning and reusing. Moreover, in locations where there is an active market for industrial land, contamination may be not a deterrent to land purchase and reuse (Howland, 2000).

The contribution of current study is to investigate the functioning of an industrial real estate market and to understand if contamination for itself or the proximity to contaminated sites can have effect on property prices. Moreover, this study contributes to the literature in Italy on contamination and hedonic price model.

### **3. Case Study**

#### *3.1. Porto Marghera industrial area*

Porto Marghera, located on the northern border of the Lagoon of Venice, just a few kilometres from the historical city of Venice, is a large industrialized area, now experiencing the difficulties of deep economic restructuring and posing huge ecological and economic problems to the Lagoon and the whole Region of Veneto in Italy. In 1998, under the Law N. 426, Porto Marghera was included in the Italian National Priority List (NPL) of contaminated sites. Figure 1 in the Appendix shows the boundaries NPL site of Porto Marghera.

The area of Porto Marghera, like most of the industrial areas in western economies, have experienced both the impacts of economic restructuring and the introduction of environmental legislation for the protection of public health and the environment, imposing liability for environmental damages. These two processes have spurred the generation of large areas of contaminated sites and vacant or underused land, opening up serious economic and ecological problems for public action. In Porto Marghera the most common harmful substances contaminating soil and water are heavy metals (e.g. lead and arsenic), oil products, polyaromatic hydrocarbons, polychlorinated biphenyls, chlorophenols, and pesticides.

Appropriate legislation has been passed to address the issue of liabilities for cleaning up these sites but the existence of appropriate policies to stimulate reuse of these properties is absent. In Italy, legislation addressed contaminated sites starting 1997—fifteen years later than in other western countries. Article 17 of Legislative Decree N. 22/1997 and its application, art. 9 of Ministerial Decree N. 471/1999, states that the party who is responsible for the pollution has to bear the cost of cleanup, even if pollutants are released into the environment by accident. Porto Marghera is one of NPL sites where remediation is managed directly by the Italian Ministry of Environment under the Law N. 471/99 and subsequent modifications. Italian Legislation is adapting to the European Directive on Environmental Liability with regard to the prevention and remedying of environmental damage (2004/35/EC) and the forthcoming Directive on Soil Protection as foreseen by the EU Soil Thematic Strategy (COM(2006)231 final).

#### *3.2 The real estate market at Porto Marghera*

The described overall legal framework is quite strict and application of legal provisions are in practice very slow and still uncertain; the impacts on real estate market conditions can be relevant because the fear of liability can have both direct and indirect effects on market dynamics, for fear of future liability



and because immediate cleanup costs may prove too high for the development project to be viable. Furthermore developers and prospective owners may fear that lenders deny financing their projects to avoid liability, and/or undervalue the property as a collateral for the loan (Alberini et al., 2005).

Confidential talks with local stakeholder reports of the high costs of these projects, including the costs to identify not only the contaminants and the appropriate techniques but also the liable parties, plus the actual costs of cleanups and the costs to eventually reuse these properties.

Such consideration at the local level are on line with previous research regarding the value of interventions and policies targeting brownfields from the perspective of the key actors involved—mainly private real estate developers (Alberini et al., 2005).

Beside the effect of environmental legislation on the actual dynamics of real estate market in Porto Marghera, economic variables need to be considered, such as the structural transformation of the global, regional and local economy, the diffusing and sprawling of residence and small and medium firm in the Region, the overall slowdown of the Italian economy since the eighties, and recently the world crisis. While the overall employment of the industrial area is almost constant since the year 2000, large and traditional industries in the area are closing down and new, much smaller firms and activities (services, constructions, repair, logistic and port related activities) are taking their place (Ente della zona industriale di Porto Marghera, 2008). Figure 2 in the Appendix, by showing on the one side the continuous decrease of traditionally established macro sector, and the growth of employment in new other industrial and service sectors, suggests the existence of a local potential demand for space and industrial property, according the new pattern of development of the area.

#### **4. Data**

The hedonic property model assumes that the price of property is determined by the different characteristics of that property, such as physical characteristics, location attributes, environmental condition, and other general economic factors and trends.

The literature review on hedonic regression and on the valuation of industrial property has been useful to select and create the variables which are relevant for our study. The literature provides evidence of the relationship between property value and physical characteristics such as the property age, size, ceiling height, office space, dock doors and rail siding (Ambrose, 1990; Hoag, 1980; Fehribach et al., 1993; Lockwood and Rutherford, 1996), even though Brown et al. (1999) found that physical attributes are insignificant, except for size.

Other studies include the effect of location variables such as distance from the main road access, airport, rail or port, and distance to the main central business district; results of these studies are contradictory (Lockwood and Rutherford, 1996; Fehribach et al., 1993; Dunse et al., 2000). In general, theory suggests that an increasing distance from a facility (or an amenity) decreases property prices, and a negative sign is expected. Others studies again complete their hedonic model with economic variables and trends variables, namely national and regional market factors, interest rate, industrial capital rate, etc. (Atteberry et al., 1993). Finally, in the previous section we have mentioned different hedonic prices studies that included the environmental status of a site as an independent variable.

In practice, to obtain data to estimate an hedonic model for industrial land is difficult, being the size of the market limited and lacking specific and organized information. Our database has been built collecting information from 3 different sources: Cadastral Registry, Conservatoria (Register of deeds) and the environmental database of the Veneto Region Hazardous Site Inventory.

Cadastral Register is a database collecting information regarding cadastral identification numbers, property size, location of the individual cadastral number, and ownership information, that are constantly updated when real property is sold. In addition, spatial data necessary to describe the geographic extent are included.

Conservatoria is a paper-based Archive in which a copy of all the real estate deeds are collected and stored. We were able to examine all the real estate transactions as identified in the cadastral register and to obtain the economic price for each of them. Besides the economic value, we have also collected all the information describing the property conveyed (size of the property, title and other important details related to the agreements between the parties for taking care of the environmental liabilities on the property).

Regional administration of Veneto, the Region in which our case study is based, has recently created a GIS database containing information on soil contamination in the NPL site of Porto Marghera, Venice (Italy). Through common geographical coordinates we were able to join the Cadastral and environmental databases, adding to the real estate properties the related environmental information, such as the action type implemented in the site (environmental assessment, remedial action, permanent or emergency safety measure, etc.) and the type and level of contamination.

Data refers to NPL Site of Porto Marghera, covering 3000 hectares of a mixed land use, mainly industrial and commercial. Real estate sales occurred between 1997 and 2008, and in Table 2 we report the main descriptive statistics. For descriptive purpose, nominal prices were adjusted to 2009 Euros, thus accounting for the effect of inflation on sale prices. The sample contains information for 187

industrial and commercial transactions, covering an overall number of 550 different real estate units. In Figure 3 in the Appendix it is possible to see their spatial distribution.

All the information has been georeferenced and ArcGIS has been used to determine the straight-line distance between property locations and various facilities, such as road access, sea terminals and sites with permanent security measures in place. For example, distance to main road access is calculated as the distance from each individual property and its nearest road access.

We consider two variables to capture the effect of environmental condition on sale prices; the first one is the distance of each transacted property from sites remediated with permanent safety measures calculated with the aim of capturing the effect of proximity to previous known contaminated sites, and we have no prior expectations on the sign of this coefficient. Furthermore, we construct a dummy variable taking the value=1 when the site has been cleaned up, 0 otherwise, to catch the effect of remediation on property prices, and we expect a positive sign for its coefficient. The variables used in estimating the HPM are summarized in Table 1 in the Appendix.

## 5. The econometric model

In this paper, an hedonic analysis is reported in which the hedonic price function is estimated using prices and characteristics of a sample of transacted properties. This procedure estimates the implicit prices of the main characteristics and reveals information on the underlying preferences for these attributes (Boxall et al., 2005). We estimate a standard first-stage hedonic model and we assume that the property market is in short-run competitive equilibrium and the hedonic industrial property price function is the locus of the point connecting buyers' bid and sellers' offer curves (Rosen, 1974).

The hedonic price function is described as follow:

$$P_i = f_i (X_1, \dots, X_h; L_1, \dots, L_k; Z_1, \dots, Z_m; E_1, \dots, E_n; A_1, \dots, A_q) \quad (1)$$

Where industrial and commercial properties are indexed by  $i$ ,  $P_i$  is the real estate sale price at nominal values, and  $f$  relates the transaction price to different characteristic of the property, better explained below:

$\mathbf{X}$  = vector of physical characteristics;  $\mathbf{L}$ = vector of location variables;  $\mathbf{Z}$ = vector of land use characteristics of the site;  $\mathbf{E}$ = vector of financial and economic variables; and  $\mathbf{A}$ = vector of environmental condition variables.

Economic theory provides little guidance regarding the choice of functional form for the hedonic price function. We decide to adopt a double natural log functional form because is widely employed in

analogous studies. Moreover, this specification allows simple interpretation of estimated coefficients as elasticities. The formal specification of our general model is the following:

$$\ln P = \alpha + \beta_1 \ln X + \beta_2 \ln L + \beta_3 \ln Z + \beta_4 \ln E + \beta_5 \ln A + \varepsilon \quad (5)$$

where the dependent variable is the natural log of sale price at nominal value.

The implicit price of different attributes is calculated from the partial derivative of sale price with respect to the different attributes.

We also estimate a similar model in which the dependent variable is the log transformation of sale price per square meter of industrial and commercial properties, considering only observations with complete information for all the lots size included in the real estate contracts (Model III in the Appendix).

#### *Descriptive statistics of our sample*

In Table 2 in the Appendix, we report the summary statistics for our samples, the pooled one, and the commercial and industrial properties samples. The original sample contained 187 real estate contracts, but we dropped some observations because data referred to financial lease contracts.

Real estate properties have been sold at an average price of 2.3 million Euros, and they have an average size of about 9700 square meters, with an average open land of 3300 square meters. Commercial properties are sold at an average price of 1.37 million Euros, with an average area of about 4100 square meters, and an average open land of 1400; whereas industrial properties are sold at higher price, on average of about 2.6 million Euros, have an average size of 14340 square meters, and almost 5000 square meters of open land. However, on average, the price per square meters of commercial properties is higher than industrial properties, respectively 335 Euros/square meters and 180 Euros/square meters. Thirty-six percent of our pooled sample is represented by commercial properties, with an average age of about 17 years; unfortunately 30 observations present a missing value for this variable. The majority of the properties (32%) are localized at the north-west boundaries of the NPL site of Porto Marghera; this area has been zoned in the past as “industrial” but the development did not took place for many years and it is still largely used as agricultural land. Within a recent mixed-use redeveloped district of Mestre (Via Torino) are localized 25% of the properties and only 17% of them are localized in the heart of the old industrial area, located on the Lagoon border.

On average, our properties are situated at a distance of about 1.4 km from a site cleaned up with permanent safety measures, and at an average distance of 1.5 km from the main road access as well from the nearest port terminals. This means that industrial and commercial properties transacted are

well located in terms of transport infrastructures, and that sites cleaned up with permanent safety measures are homogeneously distributed in all the territory investigated.

Commercial properties are on average newest than industrial properties (11 years and 22 years respectively) and are principally located in “Via Torino” area (46%), where zoning allows mixed land use and where recently large investment took place, whereas the industrial properties are mainly placed in the historical industrial area of Porto Marghera and in the “agricultural areas”. Moreover, industrial properties are situated nearest the port terminals than commercial properties (1.2 km and 1.7 km respectively), but the latter are better located as regard the main road accesses (1.4 km from commercial and 1.6 km for industrial).

For both commercial and industrial properties most sales occurred during the period 2004-2006.

## 6. Empirical results

Five different models were estimated to investigate the relationship between the sale price of an industrial and commercial real estate property and its characteristics. Table 3 in the Appendix presents the results of the hedonic price models for the real estate properties, and the regression diagnostic tests. Model I is the complete model, where the significance of the commonly used variables in HPM, as reported in the literature review, has been tested. Model II is our base model. Both Model I and Model II use as dependent variable the log of sale price at nominal value, while in Model III the log of price per square meters is used. The latter case implies a reduction in the sample numerosity which is reduced to 94 observations. Model IV and Model V relate to commercial and industrial properties subsamples respectively.

Results of Model I estimates show that the parcel extension and the age of the property are major factors explaining differences in the property sale values. The price is positively associated with the total size of the property and the actual square footage of buildings, whereas the increase in the age of the property induces a decline in the property’s value.

The coefficient of the distance to the main road (*Inroadaccess*) has the expected negative sign, but it is not significant. However, the coefficient of the distance to a previously remediated site with permanent safety measure (*Indistmise*) is significant and positively related to prices, suggesting that the proximity to a previously contaminated site does affect property price. This result may be interpreted as a presence of a contamination stigma, suggesting that this remediation option does not help in totally cancel the fear of contamination liability for prospective buyers, negatively affecting the market. On the contrary, the coefficient of the dummy *remediated*, representing properties where environmental

remediation process has been completed and certified by Law, have a significant and positive effect on the sale price.

Among all location variables, only *torino* and *oilarea* are positive and significant, increasing the price of the properties, showing the location advantages of such areas.

The specification of our Model I includes a trend variable (year of sale) to capture the inflationary component of price variation, a dummy variable for the business nature of the buyer (final utilizer or financial intermediary), which shows to be not significant, and the regional index of industrial building construction costs (*lncostrindex*). Since this latter variable shows a strong correlation with the trend variable we dropped it and we kept *lncostrindex*, to capture the economic dynamics, in its trend and cyclical components.

In Model II we dropped few explanatory variables and we estimate the base model. Results confirm the role of property size and age of the buildings as significant determinants of the sale price and generally all coefficients have the expected signs, and most of them are statistically significant at the 0.05 level. The coefficient of regional industrial building construction cost index is positive and significant showing that general macro variables affect local market. Since our dependent variable is the sale price of property at the time of the transaction, this economic trend index adds information on real estate investment conditions as well as can be used to adjust the price for inflation.

Again, remediation of contaminated properties affects properties sale prices, as shown by the coefficient of variable *remediated* which is positive and statistically significant. We lack of detailed information regarding the specific time at which remediation took place or the time at which the site was listed or de-listed; therefore we are not able to untangle the net effect of cleanups on sale price from the effect of simply recouping through sale price the costs of remediation and redevelopment. We plan to collect more information to deal with this issue. Being located farer away from sites where permanent safety measures have been implemented increases the price of the property; the same happens for properties which are located in the urban area of Via Torino, where zoning allows mixed land use and where recently large investments took place, inducing processes of gentrification.

In Model III, our response variable is the log of the property price per square meter and this model refers to 94 observations, lacking relevant information for many contracts which include exchange of several properties units. Results of model are similar to the previous one and this outcome supports the soundness of our models; in Model III the coefficient of *remediated* is no longer significant and the coefficient of *lndistmise* is negative, even if not significant, meaning that proximity to previously remediated sites with permanent safety measure increases the value of the property.

Model IV and V account for respectively the commercial properties subsample and the industrial properties subsample.

These two models confirm that the embodied characteristics of the site (lot size and age) are important being significant and with the correct sign. The subsample containing only commercial properties does not include cases of cleanups, and we dropped this variable. Location (*Torino*) of the property is important and positively affects the price. Being located far away from site with permanent safety measure increases the price of commercial property, and the coefficient *Indistmise* (0.57) is remarkably bigger than in the case of industrial properties (0.31).

Looking at the industrial properties subsample results show that prices increase if the property has been cleaned up, and the coefficients of building size and location (*Torino*) are both statistically insignificant. We speculate that these results may be connected to the specificity of the industrial composition of the area, with large plants located outside as compared with commercial activities which utilize indoor space. Furthermore the multifunctional development area located in Torino road hosts a variety of services and commerce activities which use indoor space intensively.

## 7. A Spatial Lag Model

As shown in Figure 3 in the Appendix, properties that have been exchanged in the period 1997-2008, within the NPL site of Porto Marghera exhibit a spatial pattern with some agglomeration effects. Therefore we have also used spatial statistics to estimate an hedonic price equation, assuming that the price of property is autocorrelated in space. This means that the price of each industrial and commercial property does not solely depend on its individual characteristics as assumed in previous models, but it also depends on the characteristics of the neighbour properties, including their sale prices.

Recently, a growing literature deals with spatial econometrics because it is capable to address the omitting variable bias (Anselin, 1999; Brasington et al., 2005). Example of application in real estate market can be found in Pace et al. (1998), Basu and Thibodeau (1998), Anselin and Gallo (2006).

The spatial lag model is formally:

$$p = \lambda Wp + \alpha + \beta X + \varepsilon \quad (6)$$

Where  $\mathbf{p}$  is a vector of prices,  $\mathbf{X}$  is vector of explanatory variables. Moreover,  $\lambda$  is the spatial correlation parameter and measures the average influence of neighbouring property prices on the observed price vector  $\mathbf{p}$ ,  $\alpha$  is the constant term, and  $\boldsymbol{\beta}$  is the vector of coefficients of the explanatory variables.

$\mathbf{W}$  is the standardized spatial weight matrix that incorporates the neighbourhood relations between observations that assigns the potential spatial correlation, with zero diagonal terms; and the product  $\mathbf{Wp}$  is the spatially lagged dependent variable or spatial lag.

A key element in spatial econometric is the determination of the spatial weight matrix. In our study it is based on geographic rook contiguity<sup>5</sup>: weights are non-zero when two locations share a common boundary.

Using GeoDa statistical software<sup>6</sup> we perform diagnostics for spatial dependence, which are reported in Table 4 in Appendix.

The statistics are the LM test for a missing spatially lagged dependent variable (Lagrange Multiplier (lag)), the LM test for error dependence (Lagrange Multiplier (error)), and the Moran's I, test for spatial autocorrelation (Anselin, 1999).

All the tests show highly significant results and lead to reject the null hypothesis of no spatial correlation.

After controlling for spatial dependence, we re-estimate the model with maximum likelihood approach, using the same specification as described in Model II, expect for the variable *Torino*.

Results of these estimates are reported in Table 5 in the Appendix.

The results confirm a positive and significant spatial autoregressive coefficient ( $\lambda = 0.41$ ), suggesting that a spatial dependence among property sale prices exists. Moreover, comparison with OLS Model II highlights that many parameters estimates change when using the spatial model.

When the estimation method is the ML, the use of the standard  $R^2$  is no longer appropriate, an alternative useful measure is the value of the maximized log-likelihood, possible adjusted for the number of parameters in the model in an Akaike Information Criterion (AIC). Tests are reported in Table 5 in Appendix.

## 7. Conclusions

Economic theory holds that the value of land is the discounted present value of future expected net profits from that land (Niskanen and Hamke, 1977). Schoenbaum (2002) has shown that if contamination reduces the expected future net profits, property price and contamination ought to be negatively related. Contamination may reduce property values in different ways; it may impose higher

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<sup>5</sup> Our choice is guided by previous literature (Anselin, 2002). We obtain the spatial weights matrix by first constructing a Thiessen polygon for the real estate property locations, which turns the spatial representation of the sample from points into polygons. Then, we use rook contiguity for as the criterion to define neighbours. Rook contiguity exists when two polygons share a common border. Our choice is guided by previous literature (Anselin, 2002).



transaction costs, may influence the productivity of economic activities on the site, and may increase the costs of financing or cleaning up the site.

In this paper we have investigated the effect of contamination and remediation on industrial and commercial real estate property in the NPL site of Porto Marghera, Venice using an hedonic price framework.

We found that distance from previously contaminated sites where permanent safety measure have been implemented have a positive effect on prices of nearby properties, suggesting the existence of post-cleanup stigma for this type of action. On the other hand, we found that a complete environmental remediation has a positive and significant effect on property price. Unfortunately, we were not able to disentangle the pure effect of environmental remediation benefits on price and the costs sustained for cleaning up and redeveloping the site. In fact, our data do not include information on date of listing, cleaning up, and the de-listing of the contaminated sites from the Regional Register of soil contamination.

We also found that parcel surface and the age of the property are important factors explaining variation in the property values. The price is positively associated with the total size of the property and the actual square footage of buildings, whereas the increase in the age of the property affected a decline in the property's value. Furthermore, we verified that localization in certain areas is more appealing than others. For example, if the area allows mixed land uses, this is reflected positively on the price of the real estate property.

Finally, we also estimated a spatial lag model for taking into account of spatial autocorrelation between the observations. Results of our model demonstrated the existence of spatial dependence and a remarkable change in parameters estimates. This implies that the OLS estimates are biased if the spatial log model is the correct specification. More research is needed to better investigate the influence of spatial effects on hedonic price model results.

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<sup>6</sup> The estimation is implemented within the GeoDa v.0.9.5-i (2005) environment.

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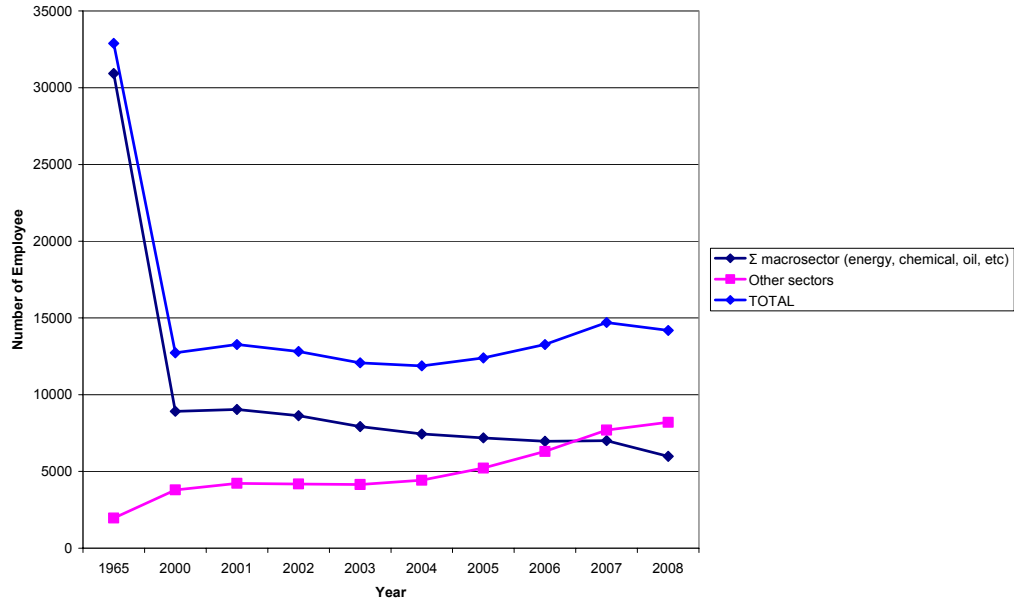
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Appendix

Figure 1: The industrial site of Porto Marghera (blu) and the boundaries of the NPL site (red)



Figure 2: Numbers of Employee at Porto Marghera (1965-2008)



Source: Ente della Zona Industriale di Porto Marghera (2008)



Figure 3: Industrial and commercial properties sold (in red) in the NPL site of Porto Marghera (in yellow), Italy



Table 1: Variable identification and description

<i>Variable</i>	<i>Variable description</i>
<i>Size (m<sup>2</sup>)</i>	Lot size of the parcel in square meters
<i>Sale price (2009 euros)</i>	Total price of the parcel in 2009 euros
<i>Open land (m<sup>2</sup>)</i>	Total open space available
<i>Sale price (euros)</i>	Total price of the parcel
<i>Building size (m<sup>2</sup>)</i>	Total size of the buildings (square footage)
<i>Age</i>	Age of building or restructuring year
<i>Other facilities</i>	Availability of offices, warehouses, cafeteria, etc
<i>Distmise</i>	Distance in meters from the property to nearest site remediated with permanent safety measures
<i>Areanorth</i>	If the site is located in the north area of the NPL of Porto Marghera
<i>Areagric</i>	If the site is located in the agricultural area of the NPL of Porto Marghera
<i>Areasouth</i>	If the site is located in the south area of the NPL of Porto Marghera
<i>Oilarea</i>	If the site is located in the oil area of the NPL of Porto Marghera
<i>Portarea</i>	If the site is located in the port area of the NPL of Porto Marghera
<i>Petrochemical</i>	If the site is located in petrochemical area of the NPL of Porto Marghera
<i>Oldarea</i>	If the site is located in the old industrial area of the NPL of Porto Marghera
<i>Oldpetrolarea</i>	If the site is located in the old petrochemical area of the NPL of Porto Marghera
<i>Torino</i>	If the site is located in the Torino area of the NPL of Porto Marghera
<i>Roadaccess</i>	Distance in meters from the property to the nearest road access
<i>Distterminals</i>	Distance in meters from the property to the nearest port terminal
<i>Commercial</i>	If the property is used for commercial activities
<i>Realestatec</i>	If the buyer is a real estate business
<i>Privatec</i>	if the buyer is a private company
<i>Financialc</i>	If the buyer is a financial society
<i>year97 – year 08</i>	sale year
<i>Remediated</i>	If the site has been already remediated
<i>Constrindex</i>	Veneto industrial building construction index

Table 2: Descriptive statistics of industrial land (N. obs=174)

	Pooled sample			Commercial			Industrial		
	Mean	St dev	Obs	Mean	St dev	Obs	Mean	St dev	Obs
Size (m <sup>2</sup> )	9676.49	26.360	160	4088.088	6782	57	14340.16	34981.30	85
Sale price (2009 euros)	2295233.68	4239855.08	174	1371480.16	86403250.3	63	2593204.7	4949378	92
Sale price (euros)	2084527.86	3917046	174	1520487.9	1692231.79	63	2810733.84	5276194.22	92
Open land (m <sup>2</sup> )	3259.49	9449	174	1403.90	2507.24	63	4952.90	12472.19	92
Building size	2012.55	4587.02	174	1302.30	1378.48	63	2816.93	6097.07	92
Age	16.61	18.88	144	11.06	12.92	53	22.33	21.61	78
Other facilities	0.419	0.495	174	0.544	0.502	63	0.272	0.447	92
Distmise	1390.93	643.33	174	1486.13	519.68	63	1255.036	720.494	92
Areanorth	0.040	0.20	174	-	-	-	0.076	0.267	92
Areagric	0.316	0.466	174	0.381	0.489	63	0.217	0.415	92
Areasouth	0.046	0.210	174	-	-	-	0.065	0.248	92
Oilarea	0.017	0.131	174	-	-	-	0.033	0.179	92
Portarea	0.063	0.244	174	0.016	0.126	63	0.109	0.313	92
Petrolchemical			174	0.016	0.126	63	0.011	0.104	92
Oldarea	0.166	0.373	174	0.079	0.272	63	0.25	0.435	92
Oldpetrolarea	0.023	0.130	174	0.016	0.126	63	0.0217	0.147	92
torino	0.247	0.423	174	0.460	0.502	63	0.098	0.299	92
Roadaccess	1,506.43	599,79	174	1380.38	266.84	63	1559.082	651.161	92
Distterminals	1,480.04	691,79	174	1750.03	570.55	63	1238.801	683.758	92
Realestatec	0.284	0.453	174	0.302	0.463	63	0.272	0.448	92
Privatec	0.333	0.472	174	0.270	0.447	63	0.348	0.479	92
Financialc	0.379	0.487	174	0.423	0.499	63	0.380	0.488	92
year97	0.055	0.222	174	0.032	0.177	63	0.065	0.248	92
year98	0.046	0.210	174	0.063	0.246	63	0.043	0.205	92
year99	0.098	0.300	174	0.095	0.296	63	0.065	0.248	92
year00	0.069	0.254	174	0.063	0.246	63	0.065	0.248	92
year01	0.086	0.281	174	0.111	0.317	63	0.087	0.283	92
Year02	0.080	0.272	174	0.032	0.177	63	0.098	0.299	92
year03	0.080	0.273	174	0.063	0.246	63	0.098	0.299	92
year04	0.150	0.357	174	0.159	0.368	63	0.130	0.339	92
year05	0.138	0.346	174	0.143	0.353	63	0.163	0.371	92
year06	0.086	0.281	174	0.143	0.353	63	0.054	0.228	92
year07	0.091	0.300	174	0.079	0.272	63	0.120	0.326	92
Remediated	0.070	0.254	174	0.016	0.126	63	0.098	0.299	92
Costrindex	115.42	11.06	174	115.93	11.16	63	115.641	10.868	92

**Table 3: Hedonic models**

	Model I		Model II		Model III*		Model IV**		Model V***	
	Parameter Estimate	t Value	Parameter Estimate	t Value	Parameter Estimate	t Value	Parameter Estimate	t Value	Parameter Estimate	t Value
Intercept	17.77	0.21	-12.05**	-3.16	-12.39**	-2.74	-5.74	-1.29	-19.88**	-3.12
Insize	0.42**	5.44	0.44**	6.24	-0.71**	-6.70	0.42**	2.93	0.52**	5.40
Inage	0.13**	2.38	-0.10*	-1.89	-0.12**	-2.18	-0.12**	-2.10	-0.16*	-1.84
remediated	0.79*	1.68	0.93**	2.96	0.43	1.14			0.776**	2.2
Indistmise	0.43*	2.64	0.25**	2.11	-0.02	-0.05	0.57*	1.94	0.31**	2.10
Inbuildingsize	0.19**	1.98	0.29**	3.17	0.48**	3.67	0.42**	2.58	0.16	1.32
Incostrindex	-1.91	-0.11	3.90**	5.14	4.35**	4.96	1.92**	2.22	5.58**	4.38
torino	0.63**	2.03	0.39**	2.21	0.32*	1.72	0.62**	3.49	-0.44	-1.24
areanorth	1.55**	2.52								
areagric	0.07	0.28								
areasouth	0.71	1.40								
oilarea	1.14*	1.89								
portarea	0.26	0.52								
oldarea	0.29	1.01								
Oldpetrolarea	-0.38	-0.48								
Inroadaccess	-0.21	-0.83								
Interminals	-0.12	-0.58								
industriale	0.01	0.06	0,05	0,34	-0,06	-0,39				
Socimmc	0.002	0.01								
Socprivatav	-0.01	-0.07								
year97	-1.76	-0.36								
year98	-1.20	-0.24								
year99	-1.27	-0.27								
year00	-0.72	-0.17								
Year01	-1.28	-0.42								
Year02	-1.98	-0.64								
Year03	0.07	0.03								
Year04	-0.46	-0.26								
Year05	0.27	0.22								
Year06	0.33	0.40								
Obs.	174		174		94		63		92	
R <sup>2</sup>	0.74		0.63		0.63		0.72		0.69	
Adj. R <sup>2</sup>	0.67		0.61		0.60		0.68		0.65	
F-value.	10.59(<.0001)		28.55 (<.0001)		16.28 (<.0001)		19.33 (<.0001)		21.25 (<.0001)	

\* The dependent variable of this model is the log of sale price per square meters, and the subsample is referred only to a single real estate unit transaction.

\*\* In this model the dependent variable is log of sale price and the sample includes only commercial properties.

\*\*\* In this model the dependent variable is log of sale price and the sample includes only industrial properties

**Table 4: diagnostics for spatial dependence**

Test statistics	Spatial weights matrix
Moran's I (error)	3.869 ( $<.00001$ )
Lagrange Multiplier (lag)	22.135 ( $<.00001$ )
Lagrange Multiplier (error)	11.154 ( $<.00001$ )

**Table 5: Spatial lag model**

	Parameter Estimate	t Value
W_Inprezzo ( $\lambda$ )	0.431	4.82
intercept	-10.8181	-2.67
Lnsize	0.1711	3.62
Lnage	-0.061	-1.07
Lndistmise	0.259	2.03
Lncostrindex	3.321	4.62
Lnbuildingsize	0.044	0.88
Remediated	1.419	4.62
Industrial	0.029	0.18
Obs.	164	
R <sup>2</sup>	0.44	
Log Likelihood	-226.10	
Akaike inf. Criteria	470.193	
Spatial lag dependence for weight matrix	19.79 ( $<.0001$ )	
Breusch-Pagan test	4.43 (0.79)	