The response of land markets to flood protection and flood experience: a hedonic price modeling on the Gironde estuary (France)

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Abstract

We develop a hedonic price model on the Gironde estuary (south of France) in order to test the impact of vulnerability to flooding on land prices. The original contribution of our analysis relies on distinguishing the respective impact of two non-structural measures on land prices - the preventive strategy consisting in a flood hazard zoning and the curative response to flood events consisting in orders for natural disaster to initiate financial compensation. This analysis is conducted on three different segments of land market (agricultural, vineyards and residential segments). We pay a particular attention to the respective importance of attractiveness factors from vulnerability ones to explain land price. We use a two-step method to estimate the model, starting with a semi-parametric model (based on the distance to the estuary) followed by a feasible generalized spatial two-stage least squares (FGS2SLS) with which we correct the model from spatial autocorrelation and endogeneity. Our main results indicate that both zoning measure and institutional response to vulnerability to flooding have a significant impact on prices, but in an opposite direction. We discuss the policy implications related to flooding prevention in regards to land use changes.

Keywords vulnerability to flooding; land prices; hedonic pricing method

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1. Introduction

Owing to global warming and rising sea levels, vulnerability to flood risks is increasing in coastal regions. Even under the most favourable climate scenarios, projected socio-economic-change (population growth) alone anticipates an increase in losses linked to flooding if neither protective investment nor adaptation takes place. Thus, in coastal and estuary areas of many European countries including France, England and others, flood and coastal risk management is undergoing a major paradigm shift as it moves from an approach dominated by investment in flood defence infrastructures to another one in which adaptations to climate change are becoming of central concern. Flood protection strategies that could be compatible with adaptation to climate change are actually designed with the aim to attain an appropriate balance between structural and non-structural risk management options (JOHNSON et al., 2007) (HANSSON et al., 2008). Scientific and experts agree that non-structural measures are more flexible and environment-friendly. Among such measures are land-use controls, regulation for flood-hazard area (through zoning), compensation mechanisms in case of damages, improved risk information and communication, etc.

However, the general public acceptance of non-structural measures cannot be taken for granted, although they are deliberated with a large consensus between water policy stakeholders (HARTMANN, DRIESSEN, 2013). Recent debate and conflicts, that followed the definition of flood hazard zoning in response to the coastal flooding brought by Xynthia in 2010 in France, have highlighted the difficulty for public regulators to initiate an effective shift to a more flexible flood protection based on the management of hazard exposures and vulnerability in a way that is socially acceptable. Indeed, the full control approach that has prevailed for water management these last decades has contributed to reduce public awareness of the possibility of floods as much as dykes and other protective measures were in place ((WOLSINK, 2010)for the Netherland case). In some respect, the resulting low level of awareness has encouraged urban development. Thus flood hazard appears to have little impact on land-use decisions. But the climate change that induces sea-level rise and extremes events for coastal and estuary regions entails a new spatial distribution of flood risks at the local scale and, consequently, of the vulnerability of floodplain areas regarding urban extension and development (MCGRANAHAN et al., 2007).

Therefore, reducing vulnerability of coastal areas by implementing alternative flood protection measures and control without hampering the economic development in these areas constitutes a major challenge for national government. However, it is important to notice that despite the risk of flood occurrence, coastal and estuarine areas carry a great attractiveness for economic activities and, among others, residential development.

Previous empirical studies of real estate markets in coastal regions (BIN et al., 2008) give evidence that the residential choice for this coastal location are stemming from a subtle trade-off between the access to coastal amenities and the level of protection for their house values. Thus, apart from the vulnerability issues with regard to climate change, the social acceptance of the shift to non-structural flood control measures would not be disconnected from the usual debate raised by the zoning effects, whereas zoning policies and strategic planning have been proved to favour the preservation of specific types of land-use development (NETUSIL, 2005). Moreover, by redirecting floods from the most vulnerable (residential zone) to the least vulnerable areas (agricultural zone), land-use planning for flood protection and water

resources management are rarely consistent with farmland protection (ERDLENBRUCH et al., 2009). Effective insurance mechanisms to ensure proper compensation of the new "victims" of the risk reallocation would be part of an innovative strategic management of flood risk, and would facilitate the acceptance of more flexible flood risk management in the future.
The empirical work we conduct tries to give an answer on the respective impact of these two non-structural measures on land prices - the preventive strategy consisting in a flood hazard zoning and the curative response to flood events consisting in orders for natural disaster to initiate financial compensation - to gain an understanding of the socio-economic mechanisms that drives land-use changes and social demand for safety with respect to flood risks in coastal and estuarine regions.

The research applied the spatial hedonic price approach (ANSELIN, LOZANO-GRACIA, 2009) to analyze the data on land sales that concern 122 municipalities that are under the influence of the Gironde estuary, for the 2002-2010 period. Located in the south of France, this area is a low developed area with numerous agricultural and natural lands, with rich landscape and famous cultural and architectural heritage. An important Bordeaux wine production is located there, making this place an important source of income from both wine-growing and tourism activities. These numerous territorial qualities, the proximity to the urban area of Bordeaux and the increasing residential attractiveness partly explain the increases in land prices even if the area is still mainly undeveloped. Furthermore, the Gironde estuary is currently in the process of reviewing its policy on flood protection and water management which consists in a flood hazard zoning called PPRI (flood risk prevention plan). Residential areas, agricultural lands and vineyards are particularly exposed to such a risk, and the increasing residential growth means considering the real effect of the current zoning policy, and questions the desirability of a zoning extension or a containment strategy development. The rest of the paper is organized as follows. The methodology section presents the methodological and empirical framework. The following section analyzes the results and the last part concludes.

2. Empirical framework

a. Study area and data

The Gironde estuary is located in the south-west of France. It is the largest estuary of Europe with a length of 75 km and a maximum of 12 km wide, totaling 635 km². This area is a low developed area with numerous agricultural and natural lands, with rich landscape and famous cultural and architectural heritage.
We limit our study area according to two distinct institutional zones: the Pays Medoc, on the left bank and the Pays Haute Gironde, on the right bank. The overall represents 122 municipalities.
Both sides of the estuary are different from a geomorphologic point of view: on the left bank, a winegrowing plain extends between sand dunes, forests and marshes, whereas vines cliffs and hillsides overhang the right side of estuary. Moreover, the historic and geographic specificities of these two zones have led to different development profiles. As physical boundaries estuary and rivers played a great role in the identities differentiation in the both zones. Even today, only a few bridges link both banks. Therefore, the left bank is under greater influence of Bordeaux city whereas historically the right bank has sometimes developed into conflict with it. The differences are particularly stark with respect to viticulture and agriculture. A hillside viticulture (right bank) and a younger viticulture later born from the development of poor lands (left bank) face each other. Each one has been

structured on specifics logics. The first covers a larger area but is composed by smaller farms, maybe more traditional, which propose red and white wines. The second produces almost exclusively red wines which can be distinguished by wines blending, is very hierarchical and is run by larger farms including some that are worldwide recognized under the designation of “Grand Cru classé de 1855”. Both sides have experienced an extraordinary expansion of vineyards. Technological innovations, the strengthening reputation of French wines and the increasing international wines demand have encouraged wine growers of both sides to plant on alluvial plains. That is why sometimes, as surprising as it may sound, vines are standing in water.
Agricultures are different too. Alongside wineries, left bank of “Médoc” is characterized by sheep and cattle farming that is famous for its quality and a vegetable gardening protected by public policy on the doorsteps of the town of Bordeaux. Farmlands of the right side of estuary are devoted to a greater extent to wine growing, but otherwise support cereals crops, forage and… asparagus which provide a very valuable supplementary income.

The database, provided by SAFER (French Land Development and Rural Establishment Companies), gathers data from land sales on the 2002-2010 period and concerns 122 municipalities that are under the influence of the Gironde estuary. It gives details on the price and the surface of the land, the date of the transaction, the land market segment (according to the expected use of the land) and the spatial localization of the land. We also use some socio-economic and spatial data from different sources (National Institute for Statistics and Economics, Corine Land Cover 2006, National Geographic Information) to characterize the local environment of the land. Finally, we use the “Gaspar” database, from the French ministry of environment, to have details regarding the vulnerability to flooding at the municipality scale.

b. Hedonic pricing method

The traditional hedonic pricing model (HPM), initially developed by Rosen (1974), has been widely used to study prices variations between different parcels of land. This is a method based on the consumer theory of Lancaster (LANCASTER, 1966), according to which one good can be described by a vector of utilities supplied by its characteristics. The main idea is that differences in characteristics of the land explain differences in land prices.

$$P_i = \alpha + \sum_k \beta_k Z_{ki} + \varepsilon_i \quad (1)$$

where P_i is the price of land i, Z is a vector of the k characteristics of land and ε_i is a normally distributed independent error term.
The characteristics of the good can be sorted in several categories: time, good’s features, environmental attributes, location and sale transaction variables. Literature on HPM applications is dense, and has focused on different type of variables. Studies in urban economics (ex. (CAPOZZA, HELSLEY, 1989)) identified significant effects of geographical and neighbouring site characteristics on real estate markets. Distance to urban area or accessibility, but also some subjective characteristics such as the architectural quality of buildings, scenic quality or environmental amenities may significantly influence prices. The HPM is also a powerful tool to identify the functional spillovers of farmland rental. As in the case of urban parcels, surfaces and buildings are strategic characteristics of farmlands but some technical attributes as well: soil qualities, slope, exposition, orientation, irrigation, lay-out of the parcels (PALMQUIST, DANIELSON, 1989). In the increasing context of

multifunctionnality of agriculture, effects of natural or landscape amenities on farmland prices have been studied (BASTIAN et al., 2002). This is particularly true for vineyards whose heritage dimension is strong and contributes to explain the prices of wine lands (CROSS et al., 2011). Finally, several studies have looked at the impact of public policies on land and real estate markets, and particularly zoning plans (NETUSIL, 2005, JAEGER, PLANTINGA, 2007). Urban or environmental zonings, designed to regulate urban growth and/or to protect environmental areas, may generate anticipation of land conversion and favor land retention and speculation which affect market prices. Flood zoning, however, refers to other mechanisms affected by risk aversion and public safety (HOLWAY, BURBY, 1990).

In our specific case, we draw particular attention to such land characteristics as vulnerability and some spatial dimensions.

Spatial effects are of particular interest when dealing with cross sectional data (PATTON, MCERLEAN, 2003) and need to be taken into account in the model formulation. Spatial dependence refers to the interdependence between two observations at two distinct points in space (LESAGE, PACE, 2009). Indeed, the price of a transaction may have been defined from prices of past land sells in the neighbourhood. We apply spatial econometric tests in order to deal with spatial dependence. Moreover, some land characteristics may be co-determinated with the price of the land. Endogeneity is usually assumed in hedonic models for the surface because of a possible simultaneity between prices and surfaces (RAPAPORT, 1997). This endogeneity problem also needs to be resolved. To account for the potential simultaneous existence of these two problems, we implement the appropriate econometric model known as a Feasible Generalized Spatial Two Stages Least Squares (FGS2SLS) model (FINGLETON, LE GALLO, 2008). To deal with such spatial econometric treatments, a spatial weights matrix W is built on the basis of an assumed spatial dependence relationship between all pairs of observations. Each element of W, w_{ij}, weights the degree of spatial dependence according to the proximity between observations i and j. This proximity is based on a distance squared decay function (equation (2)):

$$w_{ij} = \frac{1}{d_{ij}^2} \text{ where } i \neq j \tag{2}$$

where d_{ij} is the distance, in meters, between observations i and j.

c. Model specification

We distinguish different market's segments according to the destination of the land: the agricultural segment, the residential segment and the vineyard segment. This distinction is important since the price mechanisms are not supposed to be the same according to the destination of the land. Indeed, land prices are based on the economic calculation of land rent and the latter will not be the same according to the expected use of the land. Numerous studies have segmented land market in order to focus on some of them. Agricultural land values have been largely explored (PATTON, MCERLEAN, 2003, HUANG et al., 2006); few have focused on specific vineyard land prices (CROSS et al., 2011). In a context of increasing urban sprawl, some have looked at residential land values (IRWIN, BOCKSTAEL, 2004). However, few works have simultaneously studied residential and agricultural land markets (CAVAILHÈS, WAVRESKY, 2003). Our research is particularly interested in developing in parallel sub-markets hedonic functions. Finally, knowing the physical constraint of the estuary and the differences between the two river banks, we implement two models for each sub-market (right and left banks).

Our main interest is to provide an explicatory tool on land values mechanisms, on different land markets, on a territory that has to take some land use management decisions based on the vulnerability to flooding increase. The original contribution of our analysis relies on distinguishing the influence of mandatory from experienced vulnerability to flooding on land prices. This approach requires the use of two variables. The "flood hazard zoning" (called PPRI in France) is a national disposal, defined at the local scale to identify the flooding zones. This specific regulatory instrument induces that some lands located into a PPRI are more constrained in face of potential conversion or even in terms of productivity since they are more exposed to the risk of flooding. In order to integrate this vulnerability dimension into the model, we use a dummy variable (called ZPPRI) that takes the value 1 if the transaction is located in a flood hazard zone, and that takes the value 0 if else. The perceived vulnerability is not evident to define. We cannot look at the effect of a past huge flood on prices as others did (ZHAI et al., 2003) since the estuary has never known until now such a disaster. We focus on the number of orders issued by municipalities concerning a natural disaster such as flood. Such orders induce consideration of damages by insurance and we suppose it gives an idea of the experience of floods at the municipality scale. This variable does not represent the real number of flood events, but it represents the number of flood event cases considered as natural disaster by the state. The models use a dummy variable (called CatNatImax) in order to make the results comparable. This dummy is defined on the base of the distribution of the number of orders by municipality. It takes the value 1 if the municipality has known at least *n* number of orders for natural disaster such as flood between 1982 and 2011; it takes the value 0 if else. This threshold *n* has been defined for each sub-market based on the statistical distribution of the total number of orders[1] (cf. Table 1).

Number of orders	Residential segment		Agricultural segment		Vineyard segment	
	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
Mean	3.42	3.67	3.51	3.91	3.73	4.41
Threshold	4	6	4	5	4	7

Table 1. Definition of the CatNatImax threshold according to the sub-markets

Another specific point of the hedonic approach followed here consists in dealing with a particular spatial gradient of prices. Coastal amenities are expected to positively affect the prices but nothing this relationship between distance to the coast and prices may be non linear (DACHARY-BERNARD et al., 2011). That is why we apply a semi-parametric model based on the model of Robinson (1988). We only use the specific spatial variable "distance to the estuary" in a non-parametric form (PARMETER et al., 2007).

Considering all these points, the same specification (cf. Equation 3) is used for the 6 sub-models in order to allow for comparison between them.

$$\ln P_i = \alpha + \sum_k \eta_k T_{k,i} + \sum_j \beta_j C_{j,i} + \sum_l \delta_l E_{l,i} + \sum_m \varphi_m V_{m,i} + \gamma DB_i + \theta s(DE_i) + \varepsilon_i \qquad (3)$$

where lnP_i is the logarithm of the deflated price of land *i*, $T_{k,i}$ are the temporal variables (*k*=2002 to 2010, 2005 being the reference), $C_{j,i}$ are land i characteristics, $E_{l,i}$ are the variables

[1] The threshold was chosen in order to allow comparison between the results, but also to have enough observations concerned. We usually chose the 75% or the 85% quantile of the distribution, but it was modified for the left bank vineyard segment (60%).

that describe the environment of the municipality in which the land i is located, $V_{m,i}$ are the variables used to describe the vulnerability to flooding (i.e. ZPPRI and CatNatImax), DB_i is a distance to Bordeaux variable and DE_i is the distance to the estuary variable (that integrates the model according to a function s(.) unknown).

3. Results and discussion

The models were estimated using R and Stata-SE softwares from the 11 258 observations dataset. The results are presented in Table 3, Table 4 and Table 5 in Appendix. Having several models complicates the presentation of the results' analysis. We first present the specification of the price functions according to some econometric tests. We then analyse the main stylized facts that emerge from the results. We finally focus the analysis on the vulnerability issue.

a. Hedonic functions specification and estimation

In order to estimate a semi-parametric function as mentioned in equation (3), we used the R-Package "Segmented" (MUGGEO, 2008) to estimate a GAM (Generalized Additive model). The results give information in terms of significance of $s(DE_i)$, which means a change in slope in the spatial gradient. A Davies'test of non linearity (DAVIES, 1987) and a graphical analysis of the segmented model have been implemented in order to conclude on the statistical interest to use a specific non linear function between land prices and distance to the estuary[2]. Overall, the existence of a specific breakpoint (bp) has been proved for only two sub-markets: the left bank residential segment (bp at 14km) and the left bank agricultural segment (bp at 14.6km). This means that for both of them prices slightly decrease from the estuary until around 14km and, from after which the trend reverses and prices increase. This increasing section of the gradient is probably due to a sea-side attractiveness effect since the Atlantic cost and coastal lakes are situated farther west from this point. Vineyard segment on this left bank of the estuary is not concerned and knows a monotonous decreasing gradient of land prices possibly because vineyards are concentrated near the estuary. For the three other segments on the right bank of the estuary, the spatial gradient is strictly decreasing.

Once this specific function *s(.)* were defined, spatial autocorrelation and endogeneity problems were explored together in order to ensure the use of the appropriate estimating method. We implemented the three stages FGS2SLS method (FINGLETON, LE GALLO, 2008) to test the endogeneity of the surface and to look at the spatial dependence between observations:

1- Estimation of a spatial autoregressive model by the two-stage-least-squares (IV-SAR). It uses instrumental variables for both the endogenous spatial-lag variable (WLogPrix) and the endogenous regressor surface (LogSurf). Since no other exogenous variables have been proposed as good instruments, we use quasi-instruments - as Fingleton and Le Gallo did - that take values -1, 0 or 1 depending on whether the observation belongs to the lower tercile, the median one or the upper one.
2- Estimation by the method of the generalized moments (KELEJIAN, PRUCHA, 1999) of lambda (spatial autoregressive parameter) from first stage residuals.

[2] This specific approach induces numerous results not presented here, but they are available from the authors on request.

3- This last stage implements again the estimation by the two-stage-least-squares of the first stage model, after a Cochrane-Orcutt transformation of the variables (COCHRANE, ORCUTT, 1949) (FSG2SLS).

The spatial weights matrix *W* used was chosen for each land market segment on the base of the maximised Moran index criterion. The Table 2 below presents the Moran index values associated with different *W*.

Distance criteria	Residential segment		Agricultural segment		Vineyard segment	
	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank
k=1	0.46 (0.00)	0.42 (0.00)	0.24 (0.00)	0.51 (0.00)	0.28 (0.00)	0.627 (0.00)
k=2	0.43 (0.00)	0.38 (0.00)	0.23 (0.00)	0.49 (0.00)	0.30 (0.00)	0.632 (0.00)
k=10	0.35 (0.00)	0.32 (0.00)	0.22 (0.00)	0.48 (0.00)	0.27 (0.00)	0.61 (0.00)
d-threshold	0.30 (0.00)	0.28 (0.00)	0.21 (0.00)	0.43 (0.00)	0.26 (0.00)	0.58 (0.00)
Threshold value	2.5 km	5.4 km	2.1 km	9.7 km	2 km	6.2 km

Table 2. Spatial autocorrelation: Moran index for different spatial weights matrices

On the left side of the estuary, all land market segments display endogeneity of the surface variable and spatial autocorrelation between observations. We implement a FGS2SLS for each of these sub-markets. But results are less homogeneous on the right bank. Agricultural segment has an exogenous surface variable but a (light) spatial autocorrelation. Spatial dependence diagnostic (ANSELIN, 1990) favors a spatial lag model. On both vineyards and residential segments, the surface is found to be endogenous, implying to use some instrumental variables. But there is no spatial dependence on the vineyards segment, whereas there is some on the residential segment. So we implement the first stage of the FGS2SLS procedure on the vineyards sub-market, and the entire procedure on the residential segment.

Table 3, Table 4 and Table 5 in Appendix systematically produce the OLS estimation results as a reference and the final models' estimation results.

b. Some stylized facts : urbanization and attractiveness

- Structural variables

The surface variable has a negative influence on land prices on both agricultural and residential segments, whatever the estuary bank under concern. This is a usual result in the literature (XU et al., 1993) (HUANG et al., 2006) that underlines the profit maximisation strategy of landowners in selling their land in multiple smaller parcels (MILLER, 2006). This logic takes part of the urbanization process. However, this is the opposite on the vineyard segment: the surface has a positive influence on the left bank or even no influence at all on the right bank of the estuary. This reflects a willingness to pay for larger plots (CAVAILHÈS, WAVRESKY, 2003) when the land is devoted for wine growing production. It means that vineyards lands do not refer to urbanization mechanism but rather to an agricultural mechanism with a specific resistance of these areas to urbanization (PERES, 2009).

We find as well that the presence of a building (BATI) on the parcel gives it a price premium, whatever the future use of the land.

- Temporal variables

Temporal variables have a significant effect only on the residential segment of land market; the year 2005 is the reference, and estimated coefficients underline a steady increase from 2002 to 2010. This is the same progression as the property prices on the same period, so it lends us to conclude that there is actually a porosity effect between property market and land market for the specific case of residential land market. This porosity exists due to the urban component of the residential land price (CAVAILHÈS, WAVRESKY, 2003). Indeed, this porosity does not appear for the agricultural and vineyard segments. We even observe an inverse relationship on the vineyard right bank segment: temporal variables from 2007 negatively and significantly impact land prices. This result is in accordance with prices on the wine market that has witnessed important changes on the same period and even an economic crisis: wine consumption mutations, overproduction in an increasing concurrence context... (GINTRAC, 2007).

- Urban influence

The urban influence on land market prices may also be demonstrated studying the spatial gradient of prices according to distance to Bordeaux (DBDX) and urban variables (as urban density - DENSITE09 - or tourists' accommodation offer – DENSNBLITS06). We observe a negative gradient of land prices according to the distance to Bordeaux, particularly on the left bank of the estuary (where Bordeaux is located). This refers to the urbanization phenomenon that supposes urban growth and, concerning the non residential segments, the anticipations of land use conversion also labelled "growth premium" (PLANTINGA et al., 2002). This urban influence can further enhanced by the influence of the density variable: more a municipality is urbanized more the land prices are high. The proximity to urban services is here valued; however the tourist development potential does not influence prices in the same way according to the estuary bank. Vineyard sub-market is, once again, marginalized in comparison to the two others since it is not impacted (or negatively on the right bank) by this variable: tourism density does not seem to be involved in wine producer's strategies. Actually, wherever they stay, tourists come to visit Bordeaux wine areas such that wine producers do not need to be located in tourists' zone and only need to appear on wine trip tour. This is the same result for farmers on the right bank who do not seem to integrate in their strategy (and, by then, the price of their land) the tourism density. It is understandable given that the farming culture developed on the right bank mainly consists of cereal crops that are not particularly engaged in tourism activity. At the opposite, tourism density is positively valued on the left side for residential and agricultural sub-markets. It reflects the urban dimension, the attractiveness and, by then, a growth premium.

- Estuary influence

Another stylized fact may be extracted from these results. It is related to the influence of estuary as spatial externality. Indeed, proximity to estuary may induce important amenities due to accessibility to natural or recreative area. So distance to estuary (DESTUAIRE and DESTUAIRE2 if concerned) was introduced in the model as spatial variable in order to demonstrate its specific impact on land prices. As presented earlier, agricultural and residential segments know the same spatial gradient of land prices: on the left bank, a first decreasing part from the bank to a breakpoint at around 14 km and, from then to the west, an increasing part where slope is the sum of the two coefficients of DESTUAIRE and DESTUAIRE2; on the right bank, the gradient is strictly decreasing. The existence of such a breakpoint refers to the ocean attractiveness that positively influences prices. The decreasing relationship from the estuary bank demonstrates the amenity effect produced by the estuary. The particular spatial form of the gradient on the left bank suggests the co-existence of two amenity effects: one from the estuary and the second from the Atlantic coast. On the right bank, whatever the sub-market under concern, there is no breakpoint and the gradient is linearly decreasing, with a higher slope than on the left bank; it highlights the only amenity effect produced by the estuary.

- Natural environment

Finally, proportion of the municipality area under Natura 2000 (CN2000PCT) has positive influence on agricultural land prices on left bank. This point reflects the thin link between agriculture and natural environment. Indeed, contrary to the widely-held view, designation of Natura 2000 sites does not aim to put all human activity on hold. Many of the Natura 2000 sites are valuable also thanks to the way they have been managed before their designation, and it is often desirable to continue with the (TEN BRINK et al., 2011). But, unexpectedly, the same variable has a negative impact on residential land prices on the right bank. Such a natural zoning doesn't generate amenities but negative externalities as it has already been demonstrated (GIBSON et al., 2004). In our case, Natura 2000 sites on the right bank are particularly concerned with wetlands (but not necessary floodplains) that are very often associated with unhealthy environment which generate some indirect social costs (mosquitoes, moisture...).

c. Vulnerability of estuary lands: an ambiguous driver of land markets

We assess two dimensions of vulnerability to flooding. The first one refers to the ex ante dimension with the use of the flood zoning as regulatory instrument to control the risk of exposure. The second dimension is more related to the experienced flooding, in its ex post dimension, via the orders to recognize flood events as a natural disaster. This is also a regulatory instrument, but in a curative form, used in order to allow financial compensation of damages by insurances. We qualify this second dimension of "experienced" since it refers to real flooding experiences that people may have lived and during which public actors have reacted to make the event recognized by the state and, by then, by the insurances.

The overall trend is similar for each sub-market, meaning that this vulnerability effect overcomes the segmentation of land market. Nevertheless, the magnitude of this effect depends on destination of the land.

- flood hazard zoning

Indeed, the flood hazard zoning ZPPRI negatively impacts land prices on each land market segment, whatever the estuary bank. This effect is particularly small on the vineyard segment (-0.56 on the left bank and -0.4 on the right bank) whose wine production may be affected by flood events but is accustomed to such a natural environment (some vines lands are marsh vineyards). However, this impact is more important on the residential segment with coefficients of respectively -1 and -0.9 on the left and right banks, meaning that loss of value for residential land generated by flooding is integrated in the market. The effect is even more particular on the agricultural segment where the fact to be in a ZPPRI area and to induce a lower selling price than to be outside this zoning is much more important on the left bank (-1.4) than on the right bank (-0.3), but also much more important than on the residential market. This result should be partly explained by the fact that any flood event would cause significant damages at the farm scale in terms of production. The left bank agriculture is concerned with higher quality cultures and production that would probably suffer more from such an event. But, this is not enough to explain such a difference. A zoning instrument has different well known effects among which the *restriction effect* that, by limiting the use of land, reduces its price compared to the most efficient use (JAEGER et al., 2012). This restriction effect is thus much more important for non-residential land markets on which anticipation of future conversion of land exists. That is apparently the case for agricultural land market segment on the left bank of the estuary where the urban pressure on agricultural lands is important. The magnitude of the ZPPRI coefficient underlines this specific feature.

This is not the case for vineyards that seem to be more resistant to urban pressure (as already demonstrated at the stylized facts level).

- Institutional response

This first variable ZPPRI underlines more of a zoning effect than a vulnerability one. The second variable (CatNatIMax) is used in the model in order to reflect the "experienced" dimension of vulnerability, an ex post dimension. Defined on the base of a threshold (*n*) of orders for natural disaster such as flooding, it is a dummy variable (cf. Table 1). Its impact on prices is systematically positive (except for the agricultural sub market on right bank where the variable is not significant), meaning that, all things being equal, prices of lands that are located where there were more than *n* orders are relatively higher than the ones of lands located in municipalities where the number of orders is lower than *n*. Knowing that such orders for natural disaster such as flood initiate the financial compensation, a landowner would have interest to see his municipal officials engaged in such natural disaster procedure. In other words, his risk of financial loss is minimized when his administrators are very active in the refund procedure. In a way, our variable underlines the institutional effectiveness to respond to flood events. Even if it doesn't say anything according to the real number of flood events known at the municipality scale, it gives us the number of times where these events have been considered as natural disaster. And this is made possible from the moment the local institutional asks the State to recognize the event as such. This result is in line with the huge literature that deals with institutional factors of adaptation to climate change (ADGER, 2000). Indeed, the ability of a local institution to take some measures to reduce the risk of negative effects from flooding may be related to its capacity of adaptation to flood events (NÆSS et al., 2005). On the Gironde estuary, we find that such a response from municipalities to flood events is actually kind of a guarantee that financial risks are lowered. This effect is not compensating the zoning effect, but it reduces it. Land markets integrate this institutional reactivity.

4. Conclusion

The main interest of our study was to look at the respective impact of flood risk prevention as well as damage compensation as effective measures to deal with flooding risks with respect to urban development and vulnerability for coastal regions. We thus implement a hedonic price approach on different sub-markets according to the estuary bank under concern, and according to the expected use of the land (residential, agricultural or vineyard).

Such methodological protocol enables us to give evidence that residential and agricultural land market segments mainly refer to urbanization mechanism whereas vineyards segment seems more related to specific wine production logics. Moreover, the gradient of land prices according to the distance to the estuary adopts a same spatial structure on the left bank for agricultural and residential market segments, underlining an usual decreasing slope on the first part until a distance of 14 km and a more original increasing slope from then, demonstrating the Atlantic coast attractiveness.

Regarding the main focus of our analysis, we conclude that land price markets integrate the vulnerability to flooding with a homogenous manner across all sub-markets. Indeed, both flood protection (by the flood hazard zoning) and institutional response to experienced flood (by number of orders of flooding as natural disaster) have been taken into account, and both have a significant impact while they have opposite influence. More specifically, we find that identically to all sub-markets, flooding protection by zoning has a discount effect on land prices, whereas the number of natural disasters orders has a positive influence and limit sale price differential for properties located inside or outside flood hazard zone. In this way, our findings suggest that the flooding vulnerability does not constitute an obstacle to get a higher price for land properties located in municipalities that have known several orders for flooding as natural disaster. This indicates that zoning as well as natural disasters orders give land buyers an indication on the magnitude of flood risk. The main factor that can make a property more vulnerable to flood hazard threat would be the institutional failure to ensure for financial compensation in case of damages.

Apart from the Gironde estuary case, the empirical results of this study open a new query on the expected restrictive effect on residential development of the spatial extent of the flood hazard zone. Indeed, it seems to play a real limit to urban growth and to favour protection of agricultural lands. But its effect is becoming weaker when it is employed in the same time with the other non-structural measure that consists in a reactive response of local institutions to flood events aiming a financial compensation of damages. While the vines seem to provide sufficient resources to adapt to new challenges, we question the future of other agricultural lands whose owners are shared between two logics. On one side, a financial constraint leads them to convert their lands on a territory under urban pressure. On the other side, the prospect of seeing their lands sacrificed in the name of urban protection from flooding frightens them.

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Appendix

Variables	Right bank						Left bank					
	OLS		IV-SAR		FGS2SLS		OLS		IV-SAR		FGS2SLS	
Constant	15.39***	(63.2)	14.95***	(38.4)	14.46***	(38.8)	13.2***	(48.9)	12.50***	(28.4)	10.6***	(27.8)
WLogPRIX	-		0.10***	(4.8)	0.09***	(4.3)	-		0.09***	(3.3)	0.08***	(2.9)
LogSurf	-0.47***	(-19.5)	-0.56***	(-20.8)	-0.54***	(-20.7)	-0.30***	(-9.9)	-0.35***	(-10.6)	-0.33***	(-10.1)
T2002	-0.71***	(-6.9)	-0.63***	(-6.9)	-0.65***	(-6.6)	-0.35**	(-2.6)	-0.30***	(-2.57)	-0.28**	(-2.3)
T2003	-0.55***	(-5.5)	-0.47***	(-5.0)	-0.50***	(-5.2)	-0.37**	(-2.7)	-0.39***	(-3.0)	-0.41***	(-3.2)
T2004	-0.32**	(-3.2)	-0.27***	(-2.9)	-0.31***	(-3.1)	-0.1	(-0.8)	-0.1	(-0.8)	-0.14	(-1.2)
T2006	0.20*	(2.1)	0.24**	(2.7)	0.19*	(2.1)	0.44***	(3.5)	0.44***	(3.6)	0.4***	(3.4)
T2007	0.38***	(4.2)	0.41***	(4.6)	0.37***	(4.2)	0.31*	(2.4)	0.34**	(2.5)	0.27**	(2.2)
T2008	0.09	(0.9)	0.15	(1.5)	0.10	(1.1)	0.59***	(4.6)	0.56***	(4.3)	0.52***	(4.4)
T2009	-0.22*	(-2.1)	-0.17	(-1.6)	-0.20	(-1.9)	0.34*	(2.5)	0.33**	(2.4)	0.32**	(2.5)
T2010	0.21	(1.9)	0.27**	(2.5)	0.21*	(2.0)	0.07	(0.5)	0.04	(0.30)	0.17	(1.3)
BATI	2.45***	(46.6)	2.42***	(53.6)	2.43***	(46.0)	2.5***	(30.8)	2.55***	(39.4)	2.52***	(32.3)
ZPPRI	-1.05***	(-8.8)	-0.91***	(-8.3)	-0.90***	(-7.6)	-1.07***	(-9.4)	-0.98***	(-9.3)	-0.98***	(-8.1)
CatNatImax	0.64***	(4.9)	0.58***	(5.1)	0.54***	(4.1)	0.38***	(3.1)	0.30***	(2.7)	0.31**	(2.3)
CCLC2ZPCT	-0.0003	(-0.2)	0.0008	(0.5)	-0.0002	(-0.1)	0.008*	(2.3)	0.01***	(3.3)	0.008**	(2.3)
CCLC4PCT	-0.038**	(-3.3)	-0.036***	(-3.6)	-0.034***	(-3.0)	-0.02	(-1.1)	-0.02	(-1.4)	-0.01	(-0.8)
DESTUAIRE	-0.00002***	(-3.7)	-0.00002***	(-3.3)	-0.00002***	(-2.8)	-0.0001***	(-9.0)	-0.00009***	(-8.2)	-0.00009***	(-7.1)
DESTUAIRE2	-		-		-		0.0002***	(11.4)	0.0002***	(10.5)	0.0002***	(9.0)
DBDX	-0.00004***	(-10.1)	-0.00004***	(-10.3)	-0.00003***	(-9.3)	-0.00001***	(-3.6)	-0.00001***	(-4.2)	-0.00001***	(-3.5)
Densité_09	0.001***	(4.2)	0.001***	(4.1)	0.001***	(3.8)	0.001***	(5.3)	0.001***	(5.5)	0.001***	(4.4)
DensNbLits_06	0.0009	(0.2)	0.002	(0.5)	0.002	(0.3)	0.002***	(5.4)	0.002***	(5.7)	0.002***	(4.9)
Loi litto	0.71***	(5.9)	0.69***	(6.0)	0.62***	(5.2)	-0.05	(-0.4)	0.07	(0.6)	-0.006	(-0.04)
ZPaysage	0.10	(0.4)	-0.07	(-0.3)	0.08	(0.3)	0.06	(0.31)	0.09	(0.5)	0.08	(0.37)
CN2000PCT	-0.007**	(-3.0)	-0.007***	(-3.4)	-0.006***	(-3.8)	-0.0006	(-0.18)	-0.002	(-0.7)	-0.001	(-0.3)
λ			0.023						0.148			
Test Hausman spatial (prob)			21.77	(0.47)					87.6	(1e-09)		
N	4654		4654		4654		3059		3059		3059	
R^2 adjusted	0.403		0.443		0.438		0.33		0.38		0.35	
R^2 1st stage (WLN_P / LN_SUR)			0.35 / 0.82		0.36 / 0.82				0.28/ 0.82		0.31 / 0.81	
I Moran - VI (probability)			1.83	(0.068)	0.31	(0.75)			1.48	(0,14)	0,06	(0.95)
Test *J* Hansen (probability)			132.6	(0.00)	169.3	(0.00)			104.1	(0.000)	123.9	(0.000)
Test *C* endogeneity (probability)			60.43	(0.00)	67.8	(0.00)			7.34	(0.007)	9.65	(0.002)

*Lecture: for each bank, table presents the reference model («OLS »), the first stage model of the Fingleton & Le Gallo (2008) procedure (« IV-SAR », i.e. a model with endogeneous spatially lagged variable that is instrumented), and, the final model (« FGS2SLS », Feasible Generalized Spatial Two Stage Least Square). Variables of this model are transformed variables according to the Cochrane-Orcutt procedure. Significance levels are noted : 1 % '***', 5 % '**' et 10 % '*'. The tests' statistics (t de Student or z for the models estimated by two stage least squares) are given in brackets.*

Table 3. Results on the residential sub-market

Variables	Right bank				Left bank					
	OLS		Lagsar		OLS		IV-SAR		FGS2SLS	
Constant	11.42***	(33.1)	10.9***	(29.6)	13.5***	(50.8)	12.36***	(23.8)	12.97***	(24.7)
WLogPRIX	-		-		-		0.02	(0.7)	0.003	(0.07)
LogSurf	-0.27***	(-10.4)	-0.26***	(-10.4)	-0.27***	(-10.5)	-0.26***	(-8.9)	-0.27***	(-9.6)
T2002	0.05	(0.4)	0.045	(0.3)	0.07	(0.5)	0.05	(0.4)	0.08	(0.5)
T2003	-0.16	(-1.3)	-0.16	(-1.2)	-0.17	(-1.1)	-0.24**	(-1.7)	-0.18	(-1.1)
T2004	-0.15	(-1.0)	-0.16	(-1.1)	0.08	(0.5)	0.0003	(0.0)	0.08	(0.5)
T2006	0.1	(0.6)	0.08	(0.5)	-0.17	(-1.0)	-0.22	(-1.4)	-0.17	(-1.0)
T2007	0.15	(1.0)	0.14	(0.9)	0.12	(0.7)	0.02	(0.1)	0.11	(0.6)
T2008	0.04	(0.3)	0.04	(0.3)	0.11	(0.7)	0.09	(0.6)	0.12	(0.7)
T2009	-0.26*	(-1.7)	-0.28*	(-1.8)	0.13	(0.8)	0.08	(0.5)	0.14	(0.8)
T2010	0.01	(0.7)	0.11	(0.8)	0.16	(1.0)	0.08	(0.5)	0.16	(1.0)
BATI	2.88***	(31.3)	2.86***	(31.6)	2.4***	(21.8)	2.36***	(19.9)	2.40***	(22.1)
ZPPRI	-0.29**	(-2.3)	-0.27**	(-2.1)	-1.41***	(-13.9)	-1.42***	(-12.4)	-1.40***	(-12.4)
CatNatImax	0.1	(0.9)	0.12	(1.1)	0.46***	(3.5)	0.40***	(2.9)	0.45***	(3.3)
CCLC2ZPCT	-0.01***	(-4.4)	-0.01***	(-4.3)	-0.15***	(-4.2)	-0.016***	(-4.6)	-0.015***	(-4.0)
CCLC4PCT	0.04***	(2.5)	0.04***	(2.6)	-0.03	(-1.6)	-0.034*	(-1.7)	-0.030	(-1.5)
DESTUAIRE	-0.00003***	(-2.8)	-0.00002***	(-2.6)	-0.0001***	(-8.7)	-0.0001***	(-8.9)	-0.0001***	(-8.1)
DESTUAIRE2	-		-		0.0002***	(5.9)	0.0002***	(4.7)	0.0002***	(5.6)
DBDX	-0.000005	(-0.9)	-0.000004	(-0.6)	-0.00001***	(-3.2)	-0.00001***	(-3.6)	-0.00001***	(-3.1)
Densité_09	0.004***	(5.5)	0.003***	(5.4)	0.0007*	(1.8)	0.0006*	(1.9)	0.0007*	(1.8)
DensNbLits_06	-0.02***	(-2.7)	-0.02**	(-2.5)	0.0014***	(4.0)	0.0013***	(4.4)	0.0014***	(3.9)
Loi litto	0.04	(0.3)	0.02	(0.1)	-0.49***	(-3.3)	-0.45***	(-3.3)	-0.48***	(-3.2)
ZPaysage	-0.25	(-0.4)	-0.24	(-0.4)	-0.58	(-1.4)	-0.55	(-1.4)	-0.58	(-1.4)
CN2000PCT	-0.005*	(-1.7)	-0.005*	(-1.7)	0.014***	(4.3)	0.014***	(4.6)	0.013***	(4.1)
Lambda/Rho			0.04				0.037			
Test Hausman spatial (prob)							34.03	(0.07)		
N	991		991		1076		1076		1076	
R² adjusted	0.56		n/a		0.61		0.62		0.61	
R² 1st stage (WLN_P / L N_SUR)							0.45/ 0.85		0.48 / 0.85	
I Moran - VI (probability)			0.05	(0.11)			2.22	(0.03)	0.59	(0.56)
Test *J* Hansen (probability)							50.5	(0.20)	85.94	(0.04)
Test *C* endogeneity (probability)							1.46	(0.22)	0.02	(0.88)

*Lecture: for each bank, table presents the reference model («OLS »), the first stage model of the Fingleton & Le Gallo (2008) procedure (« IV-SAR », i.e. a model with endogeneous spatially lagged variable that is instrumented), and, the final model (« FGS2SLS », Feasible Generalized Spatial Two Stage Least Square). Variables of this model are transformed variables according to the Cochrane-Orcutt procedure. Significance levels are noted: 1 % '***', 5 % '**' et 10 % '*'. The tests' statistics (t de Student or z for the models estimated by two stage least squares) are given in brackets.*

Table 4. Results on the agricultural sub-market

Variables	Right bank				Left bank					
	OLS		IV-SAR		OLS		IV-SAR		FGS2SLS	
Constant	10.60***	(36.2)	8.81***	(9.8)	12.4***	(40.7)	6.0***	(4.4)	6.53***	(4.3)
WLogPRIX	-		0.16**	(2.1)	-		0.48***	(4.5)	0.44***	(3.8)
LogSurf	0.13	(0.5)	0.03	(1.2)	-0.04	(-1.6)	0.09***	(3.7)	0.06**	(2.3)
T2002	0.04	(0.3)	0.008	(0.06)	-0.01	(-0.07)	-0.04	(-0.3)	-0.01	(-0.07)
T2003	0.17	(1.2)	0.15	(1.2)	-0.07	(-0.3)	0.05	(0.3)	0.05	(0.3)
T2004	0.15	(1.0)	0.15	(1.1)	0.04	(0.2)	-0.04	(-0.2)	0.005	(0.03)
T2006	0.05	(0.3)	-0.06	(-0.4)	0.02	(0.08)	0.02	(0.1)	-0.04	(-0.2)
T2007	-0.28*	(-1.8)	-0.31**	(-2.2)	0.03	(0.17)	-0.06	(-0.3)	-0.008	(-0.05)
T2008	-0.40***	(-2.8)	-0.48***	(-3.7)	-0.06	(-0.4)	-0.07	(-0.5)	-0.11	(-0.7)
T2009	-0.41***	(-2.7)	-0.47***	(-3.4)	0.29	(1.5)	0.25	(1.4)	0.25	(1.4)
T2010	-0.32**	(-2.1)	-0.39***	(-2.6)	-0.02	(-0.1)	-0.23	(-1.3)	-0.12	(-0.7)
BATI	1.29***	(9.9)	1.20***	(8.9)	0.83***	(4.4)	0.70***	(3.5)	0.86***	(5.0)
ZPPRI	-0.48***	(-2.7)	-0.39**	(-2.2)	-0.68***	(-3.3)	-0.33	(-1.5)	-0.56***	(-3.0)
CatNatImax	0.19	(1.3)	0.21*	(1.7)	0.53***	(3.1)	0.42***	(3.1)	0.33**	(2.1)
CCLC2ZPCT	-0.008***	(-3.1)	-0.007***	(-2.7)	-0.02***	(-3.5)	-0.008**	(-2.0)	-0.01**	(-2.1)
CCLC4PCT	-0.012	(-0.9)	-0.015	(-1.3)	0.006	(0.3)	-0.01	(-0.8)	-0.006	(-0.4)
DESTUAIRE	-0.00004***	(-3.2)	-0.00004***	(-2.8)	-0.0002***	(-7.0)	-0.00008***	(-3.5)	-0.00009***	(-3.4)
DESTUAIRE2	-		-		-		-		-	
DBDX	-0.00001**	(-2.1)	-0.00005	(-1.2)	-0.00002***	(-4.7)	-0.00001**	(-2.4)	-0.00001*	(-1.9)
Densité_09	0.002***	(3.1)	0.001***	(2.7)	0.001***	(2.6)	0.001**	(-2.0)	0.001**	(2.0)
DensNbLits_06	-0.017***	(-2.9)	-0.016***	(-3.3)	-0.00007	(-0.02)	-0.003	(-1.4)	-0.002	(-0.7)
Loi litto	0.10	(0.7)	0.13	(1.0)	0.24	(1.3)	0.15	(1.0)	0.07	(0.4)
ZPaysage	0.40	(0.9)	0.17***	(3.0)	-1.27	(-1.6)	-0.73	(-1.3)	-0.36	(-0.5)
CN2000PCT	-0.003	(-1.2)	-0.004	(-1.4)	0.008*	(1.7)	0.003	(1.0)	0.005	(1.2)
λ			-0.047				0.0105			
Test Hausman spatial (prob)			18.58	(0.67)			18.8	(0.66)		
N	858		858		620		620		620	
R² adjusted	0.27		0.32		0.45		0.56		0.56	
R² 1st stage (WLN_P / LN_SUR)			0.22/0.88				0.14/ 0.87		0.17/ 0.88	
I Moran - VI (probability)			0.61	(0.54)			-1.09	(0.28)	-1.45	(0.15)
Test *J* Hansen (probability)			57.6	(0.068)			69.81	(0.006)	110.56	(0.001)
Test *C* endogeneity (probability)			0.035	(0.85)			3.69	(0.055)	1.99	(0.16)

*Lecture: for each bank, table presents the reference model («OLS »), the first stage model of the Fingleton & Le Gallo (2008) procedure (« IV-SAR », i.e. a model with endogeneous spatially lagged variable that is instrumented), and, the final model (« FGS2SLS », Feasible Generalized Spatial Two Stage Least Square). Variables of this model are transformed variables according to the Cochrane-Orcutt procedure. Significance levels are noted: 1 % '***', 5 % '**' et 10 % '*'. The tests' statistics (t de Student or z for the models estimated by two stage least squares) are given in brackets.*

Table 5. Results on the vineyard sub-market