Análisis del impacto de las inundaciones en el valor de las propiedades inmobiliarias en la ciudad de Lajeado, Brasil - Estudio de caso de viviendas unifamiliares

Analysis of the impact of flooding in the real estate value in lajeado city, brazil - case study for single-family homes

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Resumen

El valor de mercado de una propiedad es un parámetro importante para la toma de decisiones en diversos sectores de la sociedad. La selección o identificación de los aspectos que más influyen en la variación del valor de la propiedad es fundamental, ya que es a partir de estas consideraciones que pueden ser desarrollados modelos explicativos para la formación del valor de la propiedad. En Lajeado, ciudad ubicada en el sur de Brasil, las inundaciones resultantes del río Taquari son fenómenos que ocurren con cierta frecuencia. Este estudio tiene como objetivo investigar la influencia de las inundaciones en el valor de bienes inmuebles urbanos en esta ciudad. Examinamos el segmento de viviendas unifamiliares, a través de un modelo de precios hedónicos. Los datos se obtuvieron del mercado local de bienes raíces y el modelo estadístico calculado mostró un buen rendimiento, siguiendo los requisitos del análisis de regresión. Los resultados indican que las propiedades residenciales ubicadas en zonas expuestas a inundaciones tienen un valor 16% menor que las propiedades ubicadas fuera de esas áreas.

Palabras claves: Inundaciones, valor de mercado, precios hedónicos, valoración de propiedades, Brasil

Abstract

The market value of a property is an important parameter for decision making in various sectors of society. The selection and identification of the aspects that most influence the variation of the property value are fundamental, because it is from these considerations that we can develop explanatory models to establish the property value. In Lajeado, a city in southern Brazil, floods resulting from the Taquari river are a phenomenon that occurs with some frequency. This study aims at investigating the influence of these floods on urban real estate values. We analyzed the single-family home segment through a hedonic pricing model. Data were obtained from the local real estate market. The calculated model showed good statistical performance, following the regression analysis requirements. Results indicate that residential properties located in flood-prone areas have a 16% lower value than properties located outside these areas.

Keywords: Floods, market value, hedonic prices, property valuation, Brazil

1. Introduction

In last decades, the urbanization process in Brazil has grown rapidly, and the population has concentrated in a reduced space, thus producing great competition regarding the same natural resources (soil and water), and the destruction of part of the natural biodiversity (Tucci, 2008). Some of the negative effects of this urbanization process are that they impact the urban systems associated with water resources, such as water supply, sewerage and rainwater drainage. In this context, Lezcano (2004) talks about urban floods, whose frequencies and intensities have considerably increased and have caused social and economical losses in several Brazilian cities.

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According to Tucci (2008), rainwater runoff can cause floods and impact urban zones because of two processes, either combined or not. The first is flooding of natural zones, which occurs in most river-beds due to the seasonal and spatial variability of precipitations and water runoff in the basin; the second process is flooding caused by urbanization, which occurs in the urban drainage due to the soil's sealing effect or flow obstructions.

According to Eves (2004), floods do not only emphasize the climate change and its impact on the environment, but also the effect on the real estate development, which affects the property values and the capacity of owners or potential buyers to obtain loans or insurances for their properties.

The purpose of this paper is to assess the influence of floods from the Taquari river on the urban real estate value in the city of Lajeado, located in the south of Brazil. Therefore, data were collected from the local market and variables that most influence the property value in the studied segment were identified, thus creating a hedonic pricing model.

2. Floods and market values

According to Lezcano (2004), the flooding problem has considerably increased, thus requiring a more objective and rational analysis in order to prepare a plan that allows minimizing the damage caused by flooding.

In Australia, authorities have researched and mapped the flood-prone zones. According to Eves (2004), these maps allow identifying flood-prone areas as well as indicating how many times they will be subject to floods in a specific timespan. Zones are classified in four categories, from "flood-free zone" to "flood-prone zones every 5 years". This information is available for all the people involved in the real estate market, and it serves as a base for the approval of real estate appraisals, construction, property insurances and real estate financing. In some cases, the insurance company does not cover the effects of floods nor the rehabilitation costs. The property buyer must consider these costs as a long-term cost. Additionally, loan institutions in general do not finance properties that are exposed to floods.

According to Tucci (1998), an accelerated urbanization process has taken place in Brazil since the sixties, creating urban zones with deficient infrastructure, especially concerning water resources, including surface drainage. In this scenario, urban floods are bound to occur, causing significant impacts.

Along with the growth of cities, sealing is produced by roofs, streets, sidewalks and patios, among others, and part of the water that used to penetrate the ground, goes now through the drainage means, thus requiring greater flow capacity.

Tucci (1998) also points out that the United States estimated losses due to flooding in around US\$5 billions annually (in 1983). In Brazil there are few studies that quantify the global economic impact. Jica (1986, in Tucci, 1998) estimated the average annual cost of flooding in the city of Blumenau (in Santa Catarina, Brazil) as 7% of the value of all the properties of the city and around US\$22 millions for the entire valley of the Itajaí river.

Studies concerning the impact of floods indicated that housing affected by floods have a lower value compared with similar non-affected properties. In most of these studies, the identification of the economic values has been made with hedonic pricing models (Bin et al., 2011, Daniel et al., 2009, Eves, 2004, Eves et al., 2010, Lamond et al., 2010, Lezcano, 2004, Montz, 1992).

3. Materials and methods

3.1 Description of the Studied Area and Characterization of the Problem

The studied area comprises the city of Lajeado, located in the center-east of the state of Rio Grande do Sul, in the south of Brazil, in the region of the Taquari river Valley. Lajeado experienced the transition from rural to mainly urban character in the early eighties, going from an urbanization degree of 32% at the beginning of the seventies to more than 99% in 2010, which is partly due to the consecutive emancipation of rural districts and the expansion of the urban perimeter. The township's population density reached 790 inhabitants/km² in 2010, nearly 35 times more than the average population density of Brazil. These data evidence the population concentration in the city, and clearly illustrates the pressure for occupying all available areas (IBGE, 2010; Lajeado, 2012).

In geological terms, the Lajeado township is located in the geomorphologic region of the Araucaria plateau. The Taquari river (main tributary of the Jacuí river) limits the city to the east and the Forqueta river limits to the north (Figure 1). The township presents a heterogeneous relief composed by basic rocks all along. The altimetric elevations go from 20 meters (near the flooding plains of the Forqueta and Taquari rivers) to 386m (in the upper part of the city). Northeast of the city, on the Taquari river bank, there is a slope of approximately 10 meters between the urban zone of Lajeado and the river-bed (Lajeado, 2012).

Figura 1. Malla hidrográfica local. Fuente: Lajeado, 2012
Figure 1. Local Hydrographic Network. Source: Lajeado, 2012

The interest region of this research comprises the flooding areas of the Taquari river within the urban zone of Lajeado. As most Brazilian cities, according to Eckardt 2008), Lajeado did not plan its urban development and it spontaneously developed at the right side of the Taquari river, where floods are the city's biggest environmental problem. The yearly precipitation varies from 1400 to 1800 mm, which occur mainly during the winter and spring. This rainfall concentration often produces floods in the low zones close to the Taquari and Forqueta rivers (Lajeado, 2012).

Floods cause great environmental impact and affect people living in the flooding plains through the loss of material goods, proliferation of diseases transmitted by water and destruction of crops. Figures 2, 3 and 4 show the city areas where big floods occur.

Figura 2. Área central de Lajeado en inundación. Fuente: AHSUL (2012)
Figure 2. Central Area of Lajeado by Flooding. Source: AHSUL (2012)

Figura 3. Inundación en el Arroyo Saraquá - Lajeado. Fuente: AHSUL (2012)
Figure 3. Flooding in the Saraquá Stream – Lajeado. Source: AHSUL (2012)

Figura 4. Inundación en el Arroyo do Engenho – Lajeado. Fuente: AHSUL (2012)
Figure 4. Flooding in the do Engenho Stream – Lajeado. Source: AHSUL (2012)

According to Eckardt (2008), flood-prone zones are located at the elevation of 27 meters or less, considering the flooding probability due to overflow of the Taquari river, which grows approximately 15 meter above its normal level when flooding occurs. The biggest flood reported in the province took place in 1947, when the river reached the elevation of 29.92 m. According to the Master Plan of Lajeado, in its article 135, "the division of the land is prohibited for urban purposes...in flood-prone areas, unless measures have been taken to guarantee the water flow or protection against flooding", and it adopts the same elevation (Lajeado, 2006). However, some buildings were built before the enactment of the Law and there are also non-regulated buildings that were built afterwards.

Furthermore, floods can also cause damages in lower levels. Eckardt (2008) reports two floods in July and October 2001, which affected the geographical coordinates of 26.30 and 26.95, causing social and environmental impacts and generating losses of approximately US\$98,000.00 and US\$198,000.00, respectively.

Eckardt (2008) considers that the buildings located below the elevation of 26 meters already have a high risk of suffering damages in case of flooding. The analysis of the return period of different flooding levels allows the administrators and investors to assess the viability of investments and the possibility of using the land in the affected zones. Figure 5 shows the flooding map of Lajeado, which identifies the flood-prone zones.

Figura 5. Carta de inundación de Lajeado. Fuente: Eckhardt (2008)

Figure 5. Flooding Map of Lajeado. Source: Eckardt (2008)

3.2 Data Analysis Procedure

The study was based on the construction of a hedonic pricing model. These models are microeconomic models of the housing market, adjusted according to a set of conditions. The hedonic pricing theory was originally introduced by Court in 1932 and revisited later on by Griliches (1971) and Rosen (1974). For Rosen (1974), "the observed prices of the specific products and the number of each characteristic associated to each good tend to define a fixed 'hedonist' or 'implicit' price. Hedonic models are very common in literature, especially in the studies that analyze the effects of a specific feature on the property price (Bartik & Smith, 1987; Boyle & Kiel, 2001; Din et al., 2001; Smith et al., 1988).

In real estate, there are several features that must be considered at the same time, assuming different numbers in the price composition in every case. In order to build the pricing models, data are collected from the interest segment and then models are generated with the representation of the characteristics of the property, basically as in Equation 1:

$$\text{Preço} = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \dots + \alpha_k x_k + \varepsilon_e \quad (1)$$

Where $x_1, \dots, x_k$ are the features (characteristics of the property, environment and transaction); $\alpha_0, \dots, \alpha_k$ are the coefficients of this equation and ε_e is the error term. Coefficients are estimated through the regression analysis, a technique that searches a model (equation) that associates the independent variables with a dependent variable (in this case, the market value). There are several conditions (assumptions) that should be evaluated in order to verify the quality of the generated model. Among them, the most important are homoscedasticity and linearity of the proposed ratio (Equation 1), as well as the absence of multicollinearity and atypical values (Neter et al., 1990). The limits adopted for the test follow the literature standards.

3.3 Market Data Collection

The local real estate market was analyzed, and data were collected that were later used as a base for modeling hedonic prices. Data collection was made through a survey to real estate agents, appraisers and local population. The type of collected data corresponds to single-family homes. The study area included almost all neighborhoods of Lajeado. Figure 6 shows the neighborhoods' spatial distribution and the number of collected data.

Figura 6. Carta de los barrios de Lajeado y distribución de los datos de mercado recolectados. Fuente: (a) Lajeado, 2012; (b) datos recolectados
Figure 6. Map of the Lajeado Neighborhoods and Distribution of the Collected Market Data. Source: (a) Lajeado, 2012; (b) Collected data

Collected data correspond to homes offered and traded between January 2010 and May 2012; 64 data were selected for the study. In the initial analysis, several data were collected concerning each property, and then variables were chosen to define the model (Table 1).

The unit value (value of the ratio of the goods and the area, expressed in US\$/m²) was defined as the dependent variable to be explained by the independent variables, which represent the physical, economical and location characteristics. Table 1 presents the variables used in the statistical model.

Tabla 1. Variables consideradas

Table 1. Variables considered

Variable/ Variable	Tipo/ Type	Representación/ Representation
Valor de la transacción u oferta/ Value of Transaction or Offer	Cuantitativa/ Quantitative	Dólares (\$)/US Dollars (\$)
Valor unitario/ Unit Value	Cuantitativa/ Quantitative	\$/m ² /US\$/m ²
Año de la construcción/ Construction Year	Cuantitativa/ Quantitative	Año de la construcción; Ej.: 2000, 2005/ Construction year; Ex.: 2000, 2005
Área de la construcción/ Construction Area	Cuantitativa/ Quantitative	Área en m ² / Area in m ²
Área del terreno/ Site Area	Cuantitativa/ Quantitative	Área en m ² / Area in m ²
Atractivo/ Appearance	Cualitativa/ Quantitative	1=Ruin ... 20=Óptima/1=Run down ... 20=Optimal
Fecha de la información/ Information Date	Cualitativa/ Quantitative	Enero/2010=1, ... Abril/2012=28/ January/2010=1... April/2012=28
Estado de conservación/ Preservation Status	Cualitativa/ Quantitative	1=Pésimo; 2=Ruin; 3=Medio; 4=Bueno; 5=Óptimo;/ 1=Disastrous; 2=Run down; 3=Medium; 4=Good; 5=Optimal;
Oferta/ Offer	Cualitativa – binaria/ Quantitative- Binary	Oferta=2; Venta=1/ Offer = 2; Sale = 1
Inundación/ Flood	Cualitativa – binaria/ Quantitative- Binary	Área sujeta a inundaciones=1; Área no sujeta a inundaciones=0/ Flood-prone area = 1; Non flood-prone area = 0
Estándar de la construcción/ Construction Standard	Cualitativa/ Quantitative	1=Mínimo; 3=Bajo; 5=Normal; 7=Alto;/ 1=Minimum; 3=Low; 5=Normal; 7=High;

4. Presentation and analysis of results

After the statistical treatment of the survey's elements, the best model was obtained, adjusted to the real estate market value of the city of Lajeado, Brazil. The significance of the model was verified through the Fisher-Snedecor variance analysis (F test), and the individual significance of the explanatory variables was assessed through the Student's t test. The parameter of the Fisher-Snedecor test is $F_{\text{CALC}} = 15.683$, considering the minimum level (95%) of $F_{\text{CRITICAL}} = 2.011$, being the approved model in accordance with this criterion. Then, the independent variables were analyzed. Table 2 presents the estimated coefficients and the significance of each variable.

Tabla 2. Coeficientes calculados y significancia de las variables
Table 2. Calculated Coefficients and Significance of the Variables

Variable/ Variable	Coeficiente/ Coefficient	t	Significancia/ Significance (%)
Constante de la ecuación/ Equation Constant	5954.0924	-	-
Año de la construcción/ Construction Year	-2.9732	-1.7532	8.52
Área de la construcción/ Construction Area	-1.0025	-4.3018	0.01
Área del terreno/ Site Area	-0.0232	-0.2439	80.83
Atractivo/ Appearance	52.9985	7.1270	<0.01
Estado de conservación/ Preservation Status	33.8636	1.9163	6.06
Estándar de la construcción/ Construction Standard	23.3177	1.3905	17.01
Fecha de la información/ Information Date	2.8682	1.6310	10.87
Inundación/ Flood	-90.9392	-1.8445	7.06
Oferta/ Offer	32.3268	1.2520	21.60

All variables had an acceptable performance in terms of the coefficients' values and signs. The significance is also reasonable, except for the Site Area variable that reached 80% significance, indicating a weak contribution to the model. Since this is an exploratory model, this variable was maintained. With coefficients presented in Table 2, the model is described in Equation (2):

Valor Unitario = $5954.0924 - 2.9732 \cdot \text{Año de la construcción} - 1.0025 \cdot \text{Área de la construcción} - 0.0232 \cdot \text{Área del terreno} + 52.9985 \cdot \text{Atractivo} + 33.8636 \cdot \text{Estado de conservación} + 23.3177 \cdot \text{Estándar de la construcción} + 2.8682 \cdot \text{Fecha de la información} - 90.9392 \cdot \text{Inundación} + 32.3268 \cdot \text{Oferta}$

Unit Value = $5954.0924 - 2.9732 \cdot \text{Construction Year} - 1.0025 \cdot \text{Construction Area} - 0.0232 \cdot \text{Site Area} + 52.9985 \cdot \text{Appearance} + 33.8636 \cdot \text{Preservation Status} + 23.3177 \cdot \text{Construction Standard} + 2.8682 \cdot \text{Information Date} - 90.9392 \cdot \text{Flood} + 32.3268 \cdot \text{Offer}$

(2)

The coefficient of determination calculated for the model (2) is $R^2=0.7233$, which indicates that the statistical model can explain around 72% of the unit value variations (value in US dollars/m²); that is, approximately 72% of the properties' unit value variations are due to the changes in the 9 independent variables included in this model. The analysis of the assumptions (multicollinearity, normality, homoscedasticity, atypical values and others) indicated that there were no statistical problems.

5. Discussion and final considerations

Following the analysis of the significance of individual variables, global significance of the model and regression assumptions, we may conclude that the adjusted model (Equation 2) represents the collected data properly.

The values and signs of the resulting coefficients (Table 2) reflect what we expected in this type of model. We should clarify that the negative coefficient in the construction and site areas are usual in models where unit price is the dependent variable.

The **Flood** variable, which is the purpose of the present study, has a significance level of 7.06%. The estimated coefficient for this variable (hedonic price) was -90.9392 US dollars, which indicates a decrease of approximately US\$91 in the unit value of the goods subject to floods. When dividing the coefficient by the average unit value of 64 homes (US\$557.49), the value reduction due to the flood probability represents 16.3% of the unit value.

Consequently, we may conclude that the **Flood** variable is significant when explaining the properties' value, based on the used sample and the developed statistical model, that is, the study revealed that residential properties located in flood-prone areas of Lajeado tend to be less valued than others outside these areas.

This study investigated the effect of floods in residential properties of the Taquari river located in the city of Lajeado, Brazil, through a hedonic pricing model. The study presented a quantitative analysis of the microeconomic impact of this phenomenon and provides data aimed at understanding the effects and supporting the decisions on urban development or real estate investments.

6. Referencias/References

- AHSUL - Administração das Hidrovias do Sul (2012)**, Fotos. (disponible en <<http://www.dnit.gov.br>>, acceso en 4 de setiembre de 2012).
- Bartik, T.J., Smith, V.K. (1987) Urban amenities and public policy. In: E.S. Mills (ed). Handbook of regional and urban economics, v.2 (urban economics), Amsterdam: Elsevier, c.31, 1207-1254. (disponible en <http://www.sciencedirect.com/science/article/pii/S1574008087800172>)
- Bin O., Poulter B., Dumas C.F., Whitehead J.C. (2011)**, Measuring the impact of sea-level rise on coastal real estate: a hedonic property model approach., Journal of Regional Science, 51, 751-767. (disponible en <http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9787.2010.00706.x/full>)
- Boyle M.A., Kiel K.A. (2001)**, A survey of house price hedonic studies of the impact of environmental externalities, Journal of Real Estate Literature, 9, 117-144. (disponible en <http://ares.metapress.com/content/23u082061q53qpm3/>)
- Daniel V.E., Florax R.J.G.M., Rietveld P. (2009)**, Floods and Residential Property Values: A Hedonic Price Analysis for the Netherlands, Built Environment, 35, 563-576. (disponible en <http://www.ingentaconnect.com/content/alex/benv/2009/00000035/00000004/art00009>)
- Din A., Hoesli M., Bender A. (2001)**, Environmental variables and real estate prices, Urban Studies, 38, 1989-2000. (disponible en <http://usj.sagepub.com/content/38/11/1989.short>)
- Eckardt R.R. (2008)**, Geração de modelo cartográfico aplicado ao mapeamento das áreas sujeitas às inundações urbanas na cidade de Lajeado/RS. 2008. Dissertação de Maestria. Programa de Pós-Graduação em Sensoriamento Remoto, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil. (disponible en <http://www.lume.ufrgs.br/handle/10183/13755>)
- Eves C. (2004)**, The impact of flooding on residential property buyer behaviour: an England and Australian comparison of flood affected property", Structural Survey, 22 (2), 84-94. (disponible en <http://dx.doi.org/10.1108/02630800410538613>)
- Eves C., Blake A., Bryant L. (2010)**, Assessing the impact of floods and flood legislation on residential property prices. Proceedings of the International Real Estate Research Symposium (IRES), 27-29, Kuala Lumpur. (disponible en <http://eprints.qut.edu.au/32599/>)
- Griliches Z. (1971)**, Price indexes and quality change, Cambridge: Harvard University Press. (disponible en <http://www.nber.org/chapters/c6492.pdf>)
- Instituto Brasileiro de Geografia e Estatística-IBGE (2012)**, Contagem da População, IBGE, Rio de Janeiro. (disponible en <<http://www.censo2010.ibge.gov.br/painel/tooltip/dashboard.html>> , acceso en 4 de setiembre de 2012).
- Lajeado (2006)**, Lei nº 7.650, de 10 de outubro de 2006. Plano Diretor de Desenvolvimento Integrado de Lajeado. Lajeado, Brasil. (disponible en http://www.lajeado.rs.gov.br/download_anexo/index.asp?strARQUIVO=planodiretor.pdf&strDescricao=Plano Diretor , acceso en 4 de setiembre de 2012).

- Lajeado (2012)**, Prefeitura Municipal. Página del município. (disponible en <http://www.lajeado.rs.gov.br> ; acceso en: 4 de setiembre de 2012).
- Lamond J., Proverbs D., Hammond F. (2010)**, The impact of flooding on the price of residential property: A transactional analysis of the UK market, *Housing Studies* 25. (disponible en <http://www.tandfonline.com/doi/abs/10.1080/02673031003711543>)
- Lezcano L.M. (2004)**, Análise do efeito do risco de cheia no valor de imóveis pelo método dos preços hedônicos. Dissertação de Maestria. Programa de Pós-Graduação em Engenharia de Recursos Hídricos e Ambiental. Universidade Federal do Paraná, Curitiba, Brasil. (disponible en <http://dspace.c3sl.ufpr.br/dspace/handle/1884/1607>)
- Montz B.E. (1992)**, The effects of flooding on residential property values in three New Zealand communities, *Disasters*, 16, 283–298. (disponible en <http://onlinelibrary.wiley.com/doi/10.1111/j.1467-7717.1992.tb00411.x/abstract>)
- Neter J., Wassermann W., Kutner M.H. (1990)**, *Applied linear statistical models*. 3ed. Burr Ridge, USA: Richard D. Irwin.
- Rosen S. (1974)**, Hedonic prices and implicit markets: Product differentiation in pure competition, *Journal of Political Economy*, 82, 34–55. (disponible en <http://www.jstor.org/discover/10.2307/1830899?uid=3737664&uid=2&uid=4&sid=21101085970213>)
- Smith L.B., Rosen K.T., Fallis G. (1988)**, Recent development in economic models of housing markets, *Journal of Economic Literature*, 26, 29–64. (disponible en <http://www.jstor.org/discover/10.2307/2726608?uid=3737664&uid=2&uid=4&sid=21101085970213>)
- Tucci C.E.M. (2008)**, Águas urbanas, *Estudos Avançados*, 22, 97–112. (disponible en <http://www.scielo.br/pdf/ea/v22n63/v22n63a07.pdf>)
- Tucci C.E.M. (1998)**, *Drenagem urbana: gerenciamento, simulação, controle*. Porto Alegre, Brasil: Editora da UFRGS.