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# Flood prone risk and amenity values: a spatial hedonic analysis

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This study examines the impact of flood-hazard zone location on residential property prices. The study utilises data from over 2000 private residential property sales occurred during 2006 in North Shore City, New Zealand. A spatial autoregressive hedonic model is developed to provide efficient estimates of the marginal effect of flood prone risks on property prices. Results suggest that the sale price of a residential property within a flood prone area is lower than an equivalent property outside the flood prone area. The flood plain location discount is reduced by the release of public information regarding flood risk.

**Key words:** amenity value, flood hazard, information, spatial hedonic.

## 1. Introduction

The least frequently occurring natural hazards include earthquakes, volcanism, tsunami, meteorological events such as storms, and fire. While of low return frequency, natural hazards are potentially of major regional significance. In the case of flooding it is possible that many properties are in a flood-hazard zone but the owners have never experienced a flood. Although a flood-hazard zone might be based on a 1 per cent chance of occurring every year a storm causing the area to be flooded may not have occurred in the last several decades. Because of the lack of flooding experience it is likely that property owners in floodplains are not aware of the risk of living in a flood prone area. Information about natural hazards is imperfect and homeowners may fail to adequately internalise the costs associated with living in that location and rely on subjective assessments about the likelihood of personal injury and property damage caused by natural risks (Beron *et al.* 1997; Troy and Romm 2004). Consumer perception of risk is a function of personal experience with floods, the history of past flooding in the community, the level of risk that exists and how each individual responds to risks (Holway and Burby 1990). It has been suggested that recent experience with flooding raises perceived risk associated with flood prone areas and that people poorly integrate risks into their decisions, especially when the risk is of high consequence and low probability (Bartošová *et al.* 1999; Zhai *et al.* 2003; Bin and Polasky 2004; Bin and Kruse 2006).

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There appears to be a limited, but growing literature on the effects of flooding risk on property values. Much of the previous research however has been carried out in the US where major flooding events have frequently been reported and the National Flood Insurance Reform Act mandates insurance purchase. Several studies use property location vis-à-vis a flood plain and find that location in a flood plain reduces property values (Holway and Burby 1990; Harrison *et al.* 2001; Guttery *et al.* 2004). These three studies are of further interest because they show the negative consequences of flood zone location were more pronounced after the passage of the National Flood Insurance Reform Act in 1994 which requires homeowners in a plain to buy insurance. These results suggest that if the marginal purchaser is not forced to acquire hazard insurance, then the negative effect of this environmental attribute is limited by the individual's subjective assessment of the risk of loss from flooding. However, Bin and Kruse (2006) found that the National Flood Insurance program has an insignificant influence on property values in floodplains because of the current insurance program offers limited coverage. With concern over sea level rise and an increase in the frequency of adverse climate events research finds lower property prices within the flood zones in the coastal housing market. However, coastal property is exposed to natural hazards, such as wind and flooding, often commands a premium for being ocean front. Isolating the effects of proximity to the coast from risk was not attempted in these studies (Bin and Kruse 2006; Bin *et al.* 2008a,b).

This study has two aims. First, we estimate the impact of flood-hazard zone location on residential property prices from over 2000 private residential property sales occurred during 2006 in North Shore City, New Zealand. Second, we estimate the value of additional public information on exposure to flooding risks. This study builds on the existing literature dealing with flood-hazard zones by including a comprehensive range of explanatory variables into the hedonic model and by using spatial econometric analysis. In addition to controlling for location in a flood plain and the timing of the public release of flood plain maps, we use geographical information systems (GIS) data on location with respect to the coast, nearest park, nearest stream, nearest motorway access ramp, local business centre and central business district (CBD). Categorical variables are used to capture the effect of contour, quality of landscape, types and scope of views. In addition to variables describing the structural characteristics of the residential property we control for income and ethnicity. Unobserved neighbourhood characteristics are controlled with local fixed effects. Spatial economic analysis has been used to examine the effects of flood plain hazard on property values (for example, see Bin *et al.* 2008a,b). Two differences distinguish this study from earlier research. First, mandatory flood insurance, a requirement of federally backed mortgages in the US, is not required in New Zealand. This confronts the buyer with the choice of buying insurance cover or choosing to locate in an area not prone to flooding. Our data should reveal the buyer's subjective assessment about the likelihood of personal injury and property damage caused by flooding. Second, urban planners recently made maps available to prospective buyers outlining flood-hazard boundaries. We are able to control for the time when this information was made publicly available and therefore estimate the impact of its release on property values.

We find that the sale price of a residential property within a flood prone area is lower than an equivalent property outside the flood prone area. Furthermore, we find that the impact of flood plain location on property prices is dependent on the availability of flood plain maps. By controlling for spatial correlation we gain more efficient estimates compared with classical regression model. The remainder of this article is divided into four sections. Section 2 describes our econometric model, Section 3 discusses our study area and the data, Section 4 presents the empirical results of our hedonic analysis and Section 5 closes with some concluding remarks.

## 2. Econometric model

This study uses hedonic price analysis to estimate the impact of flood-hazard locations on the sale price of properties. Initially the following traditional hedonic price model is specified as:

$$\text{Log } P = \beta_1 + \beta_2 H + \beta_3 N + \beta_4 L + \beta_5 E + \varepsilon \tag{1}$$

where $P = nx1$ vector of residential sale prices and $H, N, L, E = nxk$ matrices of structural, neighbourhood, location and environmental characteristics respectively. The parameters to be estimated are $\beta_1$, $\beta_2$, $\beta_3$, $\beta_4$, $\beta_5$ and $\varepsilon$ is the random error term which is assumed to be iid $\sim N(0,\Omega)$. The semi-log form is consistent with Rosen (1974) and there is ample evidence to support this functional form as opposed to a simple linear functional form (Linneman 1980; Paterson and Boyle 2002; Kim *et al.* 2003; Bourassa *et al.* 2004). On statistical grounds the semi-log functional form corrects for heteroscedasticity between house price and the residuals (Basu and Thibodeau 1998). Given the semi-log functional form, the marginal effect of a unit change in any untransformed continuous explanatory variable (or a change in one category of a dummy variable) on sale price can be measured by $100 \times [\exp(\beta_i)-1]$ as a percentage. For log-transformed explanatory variables, the estimated coefficients measure the price elasticities with respect to a given variable.

### 2.1 Spatial correlation

Classical linear regression models assume that observations ordered in space are independent of each other. In residential property analysis, however, we expect spatial dependency among house sale prices in close proximity. Neighbourhood properties tend to be developed at the same time and thus have similar lot size, vintage and structural characteristics. Also, properties within a given vicinity may share a similar quality of public amenities and socio-economic attributes. Thus the economics underlying the development of urban areas make the spatial dependence of these characteristics and the value of residential properties almost inevitable.[1]

For the model specified in Equation (1), we first obtain estimators using ordinary least squares (OLS) and then test for spatial correlation. Then we estimate coefficients of the spatial autoregression model using maximum likelihood (ML).[2]

## 3. Data

Our study uses residential property sales data from New Zealand's fourth largest city, North Shore City. The city has an unbroken coastline of 140 km, an area of approximately 13,000 ha, and around 72,000 households. Homeownership is high (over 60 per cent), the city's population is mostly European and the median household income is NZ$76,000. The average land uptake has been 17 ha per annum over the last 5 years with only 50 ha remaining and the pressure that this has put on land supply in recent years has resulted in prices escalating sharply (Bayleys Research 2007). Between 1981 and 2004, the real price of vacant residential sections increased by around 400 per cent in North Shore (Grimes and Aitken 2005). Coastal suburbs of Northcote, Devonport, Milford, Takapuna and the East Coast Bays provide some of the most sought after and valuable residential real estate in New Zealand and comprises 16 per cent of the 1636 properties which have sold for in excess of $1 million in New Zealand in 2006 (Bayleys Research 2007).

Our data consist of 2241 transactions of individually owned freestanding residential homes recorded during the calendar year 2006. The data used in this study come from four different sources: the official database for all real estate transactions[3] provided information on sale price, date of sale, house structural variables, environmental variables and some neighbourhood characteristics for each transaction; the 2006 New Zealand Census of Population and Dwellings for additional neighbourhood characteristics (at the mesh block level); GIS for location characteristics; and North Shore City Council (NSCC) for flood zone information. The variables used in the hedonic price function are defined and described in Appendix A and the descriptive statistics appear in Table 1. House sale prices are adjusted for inflation to 2006 Quarter 1 prices using the quarterly house price index. The median selling

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[1] Refer to Appendix B for detailed explanation of spatial econometrics.

[2] The estimation is implemented within the GeoDa v.0.9.5-I (beta) environment in conjunction with R for windows 2.7.1.

[3] Property sales data were provided by Quotable Value New Zealand (QVNZ).

**Table 1** Summary statistics

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| PRICE | 581840.037 | 319848.775 | 130000.000 | 4856175.602 |
| LAND | 0.075 | 0.031 | 0.018 | 0.504 |
| BFLOOR | 182.400 | 70.803 | 40.000 | 770.000 |
| BUILT_1900–10 | 0.033 | n/a | 0.000 | 1.000 |
| BUILT_1920 | 0.026 | n/a | 0.000 | 1.000 |
| BUILT_1930–40 | 0.023 | n/a | 0.000 | 1.000 |
| BUILT_1950 | 0.053 | n/a | 0.000 | 1.000 |
| BUILT_1960 | 0.155 | n/a | 0.000 | 1.000 |
| BUILT_1970 | 0.216 | n/a | 0.000 | 1.000 |
| BUILT_1990 | 0.168 | n/a | 0.000 | 1.000 |
| BUILT_2000 | 0.211 | n/a | 0.000 | 1.000 |
| WALL_WBOARD | 0.398 | n/a | 0.000 | 1.000 |
| WALL_BRICK | 0.135 | n/a | 0.000 | 1.000 |
| WALL_MIX | 0.167 | n/a | 0.000 | 1.000 |
| WALL_ROUGHCST | 0.168 | n/a | 0.000 | 1.000 |
| WALL_OTHER | 0.020 | n/a | 0.000 | 1.000 |
| ROOF_STEEL | 0.355 | n/a | 0.000 | 1.000 |
| ROOF_OTHER | 0.031 | n/a | 0.000 | 1.000 |
| ROOF_CON | 0.707 | n/a | 0.000 | 1.000 |
| GARAGE | 1.627 | 0.709 | 0.000 | 6.000 |
| QBUNGALOW | 0.251 | n/a | 0.000 | 1.000 |
| CONTEMPORARY | 0.045 | n/a | 0.000 | 1.000 |
| VILLA | 0.034 | n/a | 0.000 | 1.000 |
| PWBUNGALOW | 0.033 | n/a | 0.000 | 1.000 |
| OTHERSTYLE | 0.022 | n/a | 0.000 | 1.000 |
| FALL | 0.323 | n/a | 0.000 | 1.000 |
| RISE | 0.262 | n/a | 0.000 | 1.000 |
| STEEP_F | 0.060 | n/a | 0.000 | 1.000 |
| STEEP_R | 0.041 | n/a | 0.000 | 1.000 |
| LANDSCAPE_G | 0.184 | n/a | 0.000 | 1.000 |
| LANDSCAPE_P | 0.054 | n/a | 0.000 | 1.000 |
| VIEW_OTHER_M | 0.174 | n/a | 0.000 | 1.000 |
| VIEW_OTHER_S | 0.275 | n/a | 0.000 | 1.000 |
| VIEW_OTHER_W | 0.018 | n/a | 0.000 | 1.000 |
| VIEW_WATER_M | 0.088 | n/a | 0.000 | 1.000 |
| VIEW_WATER_S | 0.083 | n/a | 0.000 | 1.000 |
| VIEW_WATER_W | 0.027 | n/a | 0.000 | 1.000 |
| FLOOD | 0.145 | n/a | 0.000 | 1.000 |
| FLOOD_MAP | 0.480 | n/a | 0.000 | 1.000 |
| NONEURO | 0.338 | 0.148 | 0.040 | 0.850 |
| INCOME | 0.493 | 0.132 | 0.000 | 1.000 |
| SUBURB1 | 0.158 | n/a | 0.000 | 1.000 |
| SUBURB2 | 0.057 | n/a | 0.000 | 1.000 |
| SUBURB3 | 0.005 | n/a | 0.000 | 1.000 |
| SUBURB4 | 0.013 | n/a | 0.000 | 1.000 |
| SUBURB5 | 0.050 | n/a | 0.000 | 1.000 |
| SUBURB6 | 0.031 | n/a | 0.000 | 1.000 |
| SUBURB7 | 0.034 | n/a | 0.000 | 1.000 |
| SUBURB8 | 0.141 | n/a | 0.000 | 1.000 |
| SUBURB9 | 0.049 | n/a | 0.000 | 1.000 |
| SUBURB10 | 0.004 | n/a | 0.000 | 1.000 |
| SUBURB11 | 0.019 | n/a | 0.000 | 1.000 |
| SUBURB12 | 0.021 | n/a | 0.000 | 1.000 |

**Table 1** (*Continued*)

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| SUBURB13 | 0.014 | n/a | 0.000 | 1.000 |
| SUBURB14 | 0.044 | n/a | 0.000 | 1.000 |
| SUBURB15 | 0.010 | n/a | 0.000 | 1.000 |
| SUBURB16 | 0.019 | n/a | 0.000 | 1.000 |
| SUBURB17 | 0.032 | n/a | 0.000 | 1.000 |
| SUBURB18 | 0.068 | n/a | 0.000 | 1.000 |
| SUBURB19 | 0.005 | n/a | 0.000 | 1.000 |
| CSI | 0.687 | n/a | 0.000 | 1.000 |
| D_CBD | 9969.000 | 3657.486 | 1771.000 | 16974.000 |
| D_PARK | 765.510 | 468.873 | 49.080 | 3028.560 |
| D_COAST | 1189.170 | 817.951 | 14.790 | 3300.510 |
| D_STREAM | 346.162 | 350.602 | 0.354 | 2304.910 |
| D_MW | 2481.400 | 1388.084 | 161.000 | 6087.400 |
| D_TAKAPUNA | 6049.218 | 2225.811 | 559.315 | 10579.157 |
| DMUL | 0.049 | n/a | 0.000 | 1.000 |

Table is based on estimation sample of 2241 residential property transactions occurred in North Shore City, during 2006. Summary statistics is given for variables prior to logarithmic transformation.
See Appendix A for variable descriptions.
The mean value for a dummy variable indicates the proportion of sales with the particular attribute.

price (real) for 2006 was NZ$518,056 with a minimum sale price of NZ$130,000 and a maximum of NZ$4,856,176.

### 3.1 Structural variables

Structural characteristics included as continuous variables are: land area, building floor area and the number of garages; and, as categorical variables: the decade at which the principle structure was built, exterior materials, roofing materials, roof condition and the architectural style. Both land and floor area are in natural logarithms. It is expected that an increase in any of the continuous structural variables will lead to an increase in the property prices. The architectural style of the house and decade built is expected to be correlated as each style corresponds to a distinct period of time.

### 3.2 Environmental variables

Categorical variables are used to control for the environmental amenities, namely view, contour and landscape. Categorical measures of the type of the focal point of view (water or other) and the scope (slight, moderate or wide) of the view were available. A water view was defined as having a sea, lake or harbour view. If a property has multiple view type (i.e. looks across the city or suburbs, to a lake, river or sea view), then the property was marked as having a water view. Other views were defined as city, suburban or landscape and included views of a park provided there is some depth in a built-up urban area. We combine the two variables to construct a view variable with six categories (slight other view, moderate other view, wide other view, slight water view, moderate water view or wide water view).

### 3.3 Flood variable

Out of the 78,000 buildings in North Shore City approximately 3 per cent are estimated to be affected by flood plains (NSCC 2007). It is possible that many properties have always been in a flood-hazard zone but have never experienced flooding problems. The NSCC is however legally obliged to make any information in their possession available to the public upon request under the Official Information Act and this is usually performed by means of a Land Information Memorandum (LIM) or a Project Information Memorandum (PIM). Prior to mid-2006, only information on the presence of the flood plain was public information. Flood plain maps became available mid-2006 (NSCC 2007). It is standard practice for buyers to obtain a LIM report which enables existing property owners and potentially new property owners to make informed decisions on buying a property in a flood prone area. Building or altering buildings or structures, or landscape within a floodplain requires Council consent. In our study area insurance companies do not distinguish between a flood plain property and a non-flood plain property and it is up to the property owner to decide whether or not to obtain cover against flood damage. Thus both perceived risk associated with being in a flood plain zone and planning rules that limit land use *inter alia* underpin the buyer's assessment of market value.

The FLOOD dummy variable takes a value of 1 if the property is either in the 100 year flood plain or in the flood sensitive area or both. We expect the location on flood-hazard area will have a negative effect on the price of the property. As defined by the NSCC, floodplains are the areas of land adjacent to waterways that would be inundated with floodwaters during a flood event that has a 1 per cent chance of occurring or being exceeded in every year. These are known as the '100 year floodplain' areas. The *flood sensitive areas* indicate areas of uncertainty beyond the flood plains that is within 500 mm in elevation of the predicted flood level. Approximately 14 per cent of the properties in our data are located in the flood-hazard area. Dummy variable FLOOD_MAP takes the value 1 if the property is sold after the flood plain maps became available to public – that is, after mid-2006. We include an interaction term between FLOOD and FLOOD_MAP to measure the dependency between the two variables, which will provide an estimate of the value of the information provided by the flood plain maps.

### 3.4 Neighbourhood variables

Neighbourhood characteristics include the measures of mesh block income, ethnicity and the overall quality of the immediate neighbourhood. In addition, we added a series of SUBURB dummy variables for location in submarkets to control for unobserved socio-economic characteristics (crime rate and school quality, for instance). The submarket used here is the neighbourhoods locally known as suburbs. Suburbs are different from the census geographic units called ‘area units’. Count data at the mesh block[4] level on the neighbourhood income, ethnic mix were available from the 2006 census. Using census data we construct, INCOME and NONEURO, where INCOME is the proportion of households with above \$70,000 mesh block income and NONEURO is the proportion of non-European ethnics in the mesh block.

### 3.5 Location variables

The exact location of every observation was geocoded so that we could use GIS to compute the distance between each observation and given locations. All the distances reported in Table 1 are straight line distances measured in meters. We control for the distances to the nearest park, coast, motorway access ramp, stream or creek, the distance to Auckland’s CBD, and the distance to the local business centre (Takapuna). All distances are natural log transformed to incorporate nonlinear relationships.

In a recent study, Grimes and Liang (2007) found significant impacts of the Auckland’s Metropolitan Urban Limit (MUL) on the cost of land. Given the scope of this study we included a dummy variable to measure the potential impacts of Auckland’s MUL on residential property prices. We look at the top part of the MUL and define DMUL dummy variable which takes the value 1 if the observation is within 1 km from the MUL or 0 otherwise. Transactions that occurred outside the MUL were excluded as only 0.4 per cent of the transactions fell into this category.

## 4. Results

### 4.1 Testing for spatial dependence

First we focus on the traditional OLS model (specified in Equation (1)), in order to assess the presence of spatial autocorrelation. After experimenting with different distance-based weight matrices it was found that a distance cut-off of 0.58 km better captured the overall spatial association in our data,[5] and the analysis reported henceforth are based on the $W$ with 0.58 km distance band. Moran’s $I$ statistic shows very strong evidence of positive autocorrelation in house sale prices in 2006, denoting that observations with similar prices tend to locate together. We adopted the procedure recommended by Anselin (2005) of using a robust form of Lagrange multiplier

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[4] The mesh block is the smallest geographic unit for which statistical data are collected and processed by Statistics New Zealand (Statistics New Zealand 2001).

[5] The best fitting spatial weight matrix, $W$, is chosen by comparing the goodness fit (measured by AIC and Log likelihood) of spatial autoregressive models using different spatial weight matrices.

(LM) tests for spatial error dependence and spatial lag dependence. The robust form of LM statistics indicated preference towards a spatial error model.[6] All estimation results are reported in Table 2. We incorporate spatial dependence by means of spatial autoregressive specification. The hedonic spatial error model is specified as:

$$\text{Log } P = \beta_1 + \beta_2 H + \beta_3 N + \beta_4 L + \beta_5 E + \varepsilon \tag{2}$$

$$\varepsilon = \lambda W + u \tag{3}$$

where $\lambda$ is the spatial autoregressive coefficient, $W$ is the defined distance-based spatial weight matrix, and $u$ is assumed to be a vector of iid errors. In a spatial error model, the price at any location is a function of the local characteristics but also of the omitted variables at neighbouring locations (Kim *et al*. 2003).

Estimation results from the OLS model[7] and the ML spatial error model are presented in Table 2. The OLS model achieves a reasonable fit with an adjusted $R^2$ of 0.750; however, the estimated coefficients are likely to be inefficient in the presence of spatial error correlation as explained above. To avoid incorrect inferences, we base our discussion on the estimation results from the spatial error model. Results from the ML spatial error model show that spatial dependency plays an important role in the house price estimation process. The spatial autoregressive coefficient $\lambda$ is highly significant, indicating spatial correlation indeed exists in our data. Moran's $I$ test on spatial error model depicts no evidence of remaining spatial correlation in the model.

### 4.2 Structural variables

Estimated coefficients on LAND, BFLOOR, ROOF_CON and GARAGE are significant and have the expected signs. Sale prices are higher, the higher the land area, building floor area, the more garages and the better the roof condition. Coefficients on LAND and BFLOOR are estimated elasticities, measuring the percentage change in sales price associated with a 1 per cent change in land or building floor area. The sale price is 2.4 per cent higher for properties with good roof condition. The relatively large coefficient on the building floor area variable is an indication that it may be serving as a proxy for other structural variables such as the number of bedroom and bathrooms. The marginal willingness to pay for an additional garage is about NZ$10,000 (2 per cent of a median priced property).

Quality bungalows and contemporary style houses are estimated to be priced higher compared with post-war bungalows; however, there seemed to be no significant difference between other types of architectural styles and

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[6] Refer to Anselin (2005) for an explanation of the procedure and use of test statistics.
[7] We report the results from the OLS model for comparison purposes.

**Table 2** Estimation results

| Variable | Traditional OLS model | | Spatial error model | |
|---|---|---|---|---|
| | Coefficient | SE | Coefficient | SE |
| (Intercept) | 14.457*** | 0.329 | 13.483*** | 0.527 |
| log(land) | 0.241*** | 0.015 | 0.236*** | 0.014 |
| log(bfloor) | 0.345*** | 0.016 | 0.295*** | 0.015 |
| built_1900–10 | 0.255*** | 0.064 | 0.197*** | 0.056 |
| built_1920 | 0.180*** | 0.049 | 0.158*** | 0.043 |
| built_1930–40 | 0.049 | 0.035 | 0.037 | 0.031 |
| built_1950 | 0.003 | 0.024 | 0.015 | 0.022 |
| built_1960 | −0.026 | 0.019 | 0.001 | 0.018 |
| built_1970 | −0.044*** | 0.016 | −0.019 | 0.015 |
| built_1990 | 0.046** | 0.018 | 0.065*** | 0.017 |
| built_2000 | 0.113*** | 0.020 | 0.140*** | 0.019 |
| wall_wboard | 0.034** | 0.015 | 0.020 | 0.014 |
| wall_brick | −0.010 | 0.019 | −0.011 | 0.018 |
| wall_mix | 0.033* | 0.018 | 0.025 | 0.017 |
| wall_roughcst | 0.051*** | 0.020 | 0.035* | 0.018 |
| wall_other | 0.022 | 0.032 | −0.018 | 0.028 |
| roof_steel | −0.015 | 0.010 | −0.007 | 0.009 |
| roof_other | 0.029 | 0.024 | 0.018 | 0.021 |
| roof_con | 0.005 | 0.012 | 0.024** | 0.011 |
| garage | 0.026*** | 0.007 | 0.019*** | 0.006 |
| qbungalow | 0.028** | 0.012 | 0.033*** | 0.011 |
| contemporary | 0.063*** | 0.021 | 0.043** | 0.019 |
| villa | 0.078 | 0.060 | 0.041 | 0.052 |
| pwbungalow | 0.045 | 0.042 | 0.007 | 0.037 |
| otherstyle | 0.063** | 0.029 | 0.039 | 0.025 |
| fall | −0.024** | 0.010 | −0.030*** | 0.009 |
| rise | −0.019* | 0.011 | −0.012 | 0.010 |
| steep_f | −0.078*** | 0.019 | −0.064*** | 0.017 |
| steep_r | −0.067*** | 0.022 | −0.053*** | 0.020 |
| landscape_g | 0.015 | 0.011 | 0.008 | 0.010 |
| landscape_p | −0.014 | 0.018 | −0.001 | 0.016 |
| view_other_m | −0.015 | 0.012 | −0.001 | 0.011 |
| view_other_s | 0.004 | 0.010 | 0.009 | 0.009 |
| view_other_w | 0.001 | 0.031 | 0.019 | 0.028 |
| view_water_m | 0.095*** | 0.017 | 0.093*** | 0.015 |
| view_water_s | 0.035** | 0.017 | 0.037** | 0.015 |
| view_water_w | 0.299*** | 0.028 | 0.248*** | 0.026 |
| flood | −0.059*** | 0.016 | −0.064*** | 0.014 |
| flood_map | 0.015* | 0.009 | 0.010 | 0.008 |
| flood*flood_map | 0.045** | 0.023 | 0.041** | 0.020 |
| noneuro | −0.088** | 0.044 | −0.008 | 0.045 |
| income | 0.236*** | 0.041 | 0.151*** | 0.041 |
| csi | −0.055*** | 0.011 | −0.029*** | 0.010 |
| log(d_cbd) | −0.020 | 0.031 | 0.045 | 0.062 |
| log(d_park) | −0.025*** | 0.008 | −0.007 | 0.011 |
| log(d_coast) | −0.070*** | 0.006 | −0.076*** | 0.010 |
| log(d_stream) | −0.001 | 0.005 | 0.000 | 0.005 |
| log(d_mw) | −0.033*** | 0.011 | 0.020 | 0.021 |
| log(d_takapuna) | −0.170*** | 0.024 | −0.157*** | 0.048 |
| dmul | −0.014 | 0.022 | −0.029 | 0.039 |
| suburb1 | −0.107*** | 0.028 | −0.095* | 0.048 |

**Table 2** (*Continued*)

| Variable | Traditional OLS model | | Spatial error model | |
|---|---|---|---|---|
| | Coefficient | SE | Coefficient | SE |
| SUBURB2 | 0.042* | 0.023 | 0.054 | 0.039 |
| SUBURB3 | 0.157** | 0.061 | 0.064 | 0.077 |
| SUBURB4 | 0.094** | 0.044 | 0.122 | 0.080 |
| SUBURB5 | 0.223*** | 0.047 | 0.350*** | 0.091 |
| SUBURB6 | 0.021 | 0.026 | 0.029 | 0.034 |
| SUBURB7 | −0.094*** | 0.032 | 0.000 | 0.062 |
| SUBURB8 | −0.166*** | 0.024 | −0.091*** | 0.035 |
| SUBURB9 | −0.115*** | 0.025 | −0.055 | 0.038 |
| SUBURB10 | −0.266*** | 0.072 | −0.182** | 0.071 |
| SUBURB11 | 0.077** | 0.035 | 0.120** | 0.054 |
| SUBURB12 | 0.054 | 0.043 | 0.077 | 0.068 |
| SUBURB13 | 0.127*** | 0.037 | 0.154*** | 0.056 |
| SUBURB14 | −0.189*** | 0.037 | −0.076 | 0.051 |
| SUBURB15 | 0.089** | 0.043 | 0.079 | 0.055 |
| SUBURB16 | −0.046 | 0.035 | −0.049 | 0.056 |
| SUBURB17 | 0.015 | 0.047 | 0.213*** | 0.076 |
| SUBURB18 | 0.075*** | 0.025 | 0.040 | 0.044 |
| SUBURB19 | 0.139** | 0.059 | 0.045 | 0.063 |
| $\lambda$ | n/a | n/a | 0.773*** | n/a |
| ADJUSTED $r^2$ | 0.751 | | n/a | |
| LOG LIKELIHOOD | n/a | | 799.013 | |
| AIC | −1129.7 | | −1456 | |
| MORAN'S I STATISTIC | 0.5631*** | | −0.008 | |
| LM ERROR | 504.5873*** | | n/a | |
| LM LAG | 58.7447*** | | n/a | |
| RLM ERROR | 468.1071*** | | n/a | |
| RLM LAG | 22.2644*** | | n/a | |

Note: Results are based on data for 2241 transactions of individually owned freestanding residential homes recorded in 2006. Dependent variable is the natural log of sale prices.
SEs are based on heteroscedasticity corrected covariance matrices.
See Appendix A and Table 1 for variable definitions and descriptive statistics, respectively.
*Significant at the 90% confidence level, **significant at the 95% confidence level, ***significant at the 99% confidence level.

post-war bungalows. The lack of significance may well be due to the expected colinearity between the decade built and the architectural style of the house. Newer houses (built in the 1990–2000s) are estimated to be of higher price than the houses built in the 1980s. It is likely that houses built in the 1900s–1920s command a significant premium because of their historical attributes. Results suggest that the sale price of houses built in the 1900–1910s and 1920s are 21.8 per cent and 17.2 per cent higher than the price of houses built in the 1980s, respectively. Houses with roughcast exterior walls also command a premium over houses with fibre cement exterior walls and these price differences are statistically significant. Fibre cement exterior featured houses were identified as being at risk of weather-tightness problems hence significant positive coefficients on the abovementioned exterior material is as expected.

### 4.3 Environmental variables

All contour dummy variables except RISE are highly significant and have negative coefficients suggesting that houses on elevated land are discounted in the market relative to houses on level surfaces. Landscape quality was not found to impact property prices. Consistent with other studies, water views are found to command a premium (for example, Benson *et al.* 1998; Seiler *et al.* 2001; Bourassa *et al.* 2004). Our findings show that properties with a wide view of water sell for approximately 28 per cent more than properties with no appreciable views, all else constant. Marginal willingness to pay for a wide water view calculated at the median property price is about NZ$145,700. Premia for a slight water view and moderate water view are estimated to be 4 per cent and 10 per cent, respectively. Interestingly, we find no significant difference between the sale price of a property with other views and that of an otherwise similar property with no appreciable view which suggests that the price effect of visible development or roads is no different from having no appreciable views.

### 4.4 Flood variable

The main focus of our study is to ascertain the effect of perceived flood risk on property prices. Estimated coefficients from this model yield some interesting results. We find that there is a significant negative relationship between property prices and flood plain location, and in addition, this relationship is dependent on the availability of floodplain maps at the time of the sale. After controlling for the interdependency, main effect of FLOOD_MAP becomes statistically insignificant. Estimated coefficients for FLOOD together with the interaction term suggest that location in a flood risk zone lowers property prices compared with a property located outside the flood risk zone, *ceteris paribus*, and this discount is less pronounced after the flood plain maps became available. Estimated marginal effects reveal that a flood plain property is priced 6.2 per cent lower than an otherwise similar house located outside the flood plain, if it was sold before the flood plain maps were available. A flood plain property is priced 2.3 per cent lower compared with a house located outside the flood plain if it was sold when the flood plain maps were available to the public, all else constant. Given the median residential property price, the marginal willingness to avoid being located within a flood-hazard zone is approximately NZ$32,300 if the property was sold before the availability of floodplain maps, where as it is approximately NZ$11,850 if the property was sold after.

The estimated discount associated with location in the flood zone is consistent with other previous studies (for example, 7.8 per cent in Bartošová *et al.* 1999; Bin *et al.* 2008b; 5.8 per cent in Bin and Polasky 2004; 4.2 per cent in Troy and Romm 2004; 11 per cent in Bin *et al.* 2008a; and 5–10 per cent in Bin and Kruse 2006). Our results are relatively lower which could be explained by the lack of recent flood experience in North Shore City. People poorly integrate the risks associated with flood prone areas, when buying a residential property, could be a further reason for a relatively lower discount.

### 4.5 Location variables

Estimated coefficients on the distance related location variables have expected signs except for D_CBD, D_STREAM and D_MW. Property prices appear to fall with distance from the local business centre, nearest coast and nearest park. However, only the effects of distance to coast and local centre are statistically significant at the 90 per cent level. Positive coefficient on D_MW may be capturing the annoyance factor of being close to the motorway access ramp, such as noise and air pollution. The negative coefficient on D_CBD suggests that North Shore is becoming a monocentric city.

Estimated coefficients reveal that on average, a 1 per cent increase in the distance to coast and Takapuna will lead property prices to fall by 0.076 per cent, and 0.157 per cent, respectively, all else constant. The DMUL variable measures the effect of the Auckland's MUL on property prices. Results from our model shows that properties just inside (within 1 km) the MUL are priced less than the inner most properties, however this difference is not statistically significant. As explained in Grimes and Liang (2007), it is possible that in early years properties just inside the MUL to have a neighbourhood which is more rural in character and priced lower than the properties further inside but as metropolitan area has urbanised, properties just inside will no longer bear this discount. On the contrary, properties just inside the MUL have some advantages such as having easy access to the country side (Grimes and Liang 2007) and nullify the discount of having rural neighbourhoods.

### 4.6 Neighbourhood variables

Percentage of non-European population in the neighbourhood has a negative relationship with property prices; however, this relationship is statistically insignificant. As expected, the proportion of high income[8] households in the neighbourhood positively impacts the property prices. Estimated results reveal that a unit increase in the proportion of high income households in the mesh block increases property prices by about 16.3 per cent. The marginal impact of an above average overall quality of the immediate surrounding is estimated to be approximately 2.9 per cent.

Coefficients on submarket dummy variables measure the sale price differentials between each suburb and Albany. Coastal suburbs of Devonport, Takapuna, Murrays Bay and Mairangi Bay command significant premiums over Albany. Hillcrest, Birkenhead and Glenfield, on the contrary bear significant discounts. There is no evidence of any significant sales price difference

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[8] Above NZ$ 70,000.

in the rest of the suburbs, compared with Albany. It is estimated that the property prices in Devonport are approximately 41.9 per cent higher than that in Albany.

## 5. Conclusion

Several studies have found that location in a flood plain reduces property prices (for instance, Holway and Burby 1990; Harrison *et al.* 2001; Bin and Polasky 2004; Guttery *et al.* 2004; Bin and Kruse 2006; Bin *et al.* 2008a,b). Most studies are based in the US where major flooding events have been reported and the National Flood Insurance Reform Act mandates insurance purchase for properties holding federally backed mortgages. This study differs from abovementioned studies in at least two areas. First, buyer perception of risk is based on a subjective assessment of the likelihood of personal injury and property damage caused by flooding. This assessment is based primarily on public information available to all participants in the market. Given that there is no compulsion to buy insurance our results show that buyers internalise the value of risk into their willingness to pay. Second, we were able to examine the impact of disseminating additional public information regarding flood risks. The reduction in the discount once information on exposure to risk was announced appears to be consistent with risk averse preferences.

We find evidence of strong spatial correlation in the residuals of the traditional hedonic model and incorporate residual spatial dependence by means of spatial autoregressive specification. Our results show that the sale price of a residential property situated within a flood prone area is significantly lower than a comparable property located outside. Moreover, we find that the discount associated with location in flood prone area is dependent on whether publicly available flood plain maps were available at the time of sale. Our results show that the discount associated with the location in a flood risk zone is lowered by the release of additional public information provided by the flood plain maps.

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## Appendix A

### Definition of variables

| Variable | Description |
|---|---|
| PRICE | House sale price adjusted to 2006 quarter 1 prices |
| LAND | Land area of the property in hectares |
| BFLOOR | Sum of all living spaces in square meters |
| BUILT_1900–10 | Dummy variable for the decade that the principle structure was built (1 if built in 1900–10, 0 otherwise) |
| BUILT_1920 | Dummy variable for the decade that the principle structure was built (1 if built in 1920, 0 otherwise) |
| BUILT_1930–40 | Dummy variable for the decade that the principle structure was built (1 if built in 1930–40, 0 otherwise) |
| BUILT_1950 | Dummy variable for the decade that the principle structure was built (1 if built in 1950, 0 otherwise) |
| BUILT_1960 | Dummy variable for the decade that the principle structure was built (1 if built in 1960, 0 otherwise) |
| BUILT_1970 | Dummy variable for the decade that the principle structure was built (1 if built in 1970, 0 otherwise) |
| BUILT_1990 | Dummy variable for the decade that the principle structure was built (1 if built in 1990, 0 otherwise) |
| BUILT_2000 | Dummy variable for the decade that the principle structure was built (1 if built in 2000, 0 otherwise)<br>The omitted category is '1980' |
| WALL_WBOARD | Dummy variable for Wall construction material (1 if Weatherboard, 0 otherwise) |
| WALL_BRICK | Dummy variable for Wall construction material (1 if Brick, 0 otherwise) |
| WALL_MIX | Dummy variable for Wall construction material (1 if Mix Material, 0 otherwise) |
| WALL_ROUGHCST | Dummy variable for Wall construction material (1 if Roughcst, 0 otherwise) |
| WALL_OTHER | Dummy variable for Wall construction material (1 if Other materials, 0 otherwise)<br>The omitted category is Fibre Cement |
| ROOF_CON | Dummy variable for roof condition (1 if good, 0 otherwise) |
| ROOF_STEEL | Dummy variable for Roof construction material (1 if Steel or Galvanised Iron, 0 otherwise) |
| ROOF_OTHER | Dummy variable for Roof construction material (1 if Other materials, 0 otherwise)<br>The omitted category is 'Tile' |
| GARAGE | Number of formed car parks |
| QBANGALOW | Dummy variable for Architectural style of the house (1 if Quality Bungalow, 0 otherwise) |

## Appendix A (*Continued*)

| Variable | Description |
|---|---|
| CONTEMPORARY | Dummy variable for Architectural style of the house (1 if Contemporary, 0 otherwise) |
| VILLA | Dummy variable for Architectural style of the house (1 if Villa, 0 otherwise) |
| PWBUNGALOW | Dummy variable for Architectural style of the house (1 if Pre-War Bungalow, 0 otherwise) |
| OTHERSTYLE | Dummy variable for Architectural style of the house (1 if Other styles, 0 otherwise)<br>The omitted category is 'Post-War Bungalow' |
| FALL | Dummy variable for Contour (1 if Easy/Moderate Fall, 0 otherwise) |
| RISE | Dummy variable for Contour (1 if Easy/Moderate Rise, 0 otherwise) |
| STEEP_F | Dummy variable for Contour (1 if Steep Fall, 0 otherwise) |
| STEEP_R | Dummy variable for Contour (1 if Steep Rise, 0 otherwise)<br>The omitted category is 'Level' |
| LANDSCAPE_G | Dummy variable for the quality of landscaping (1 if good quality, 0 otherwise) |
| LANDSCAPE_P | Dummy variable for the quality of landscaping (1 if poor quality, 0 otherwise)<br>The omitted category is 'Average quality' |
| VIEW_OTHER_M | Dummy variable for a view (1 if other view of moderate scope, 0 otherwise) |
| VIEW_OTHER_S | Dummy variable for a view (1 if other view of slight scope, 0 otherwise) |
| VIEW_OTHER_W | Dummy variable for a view (1 if other view of wide scope, 0 otherwise) |
| VIEW_WATER_M | Dummy variable for a view (1 if water view of moderate scope, 0 otherwise) |
| VIEW_WATER_S | Dummy variable for a view (1 if water view of slight scope, 0 otherwise) |
| VIEW_WATER_W | Dummy variable for a view (1 if water view of wide scope, 0 otherwise)<br>The omitted category is 'no appreciable view' |
| FLOOD | Dummy variable for flood hazard area (1 if the house is within the flood hazard area, 0 otherwise) |
| FLOOD_MAP | Dummy variable for flood map availability at the time of the sale (1 if the house is sold after July 2006, 0 otherwise) |
| NONEURO | Proportion of non European ethnic groups in the mesh block |
| INCOME | Proportion of houses with family income above $70,000 in the mesh block |
| SUBURB1 | Dummy variable for a suburb (1 if Birkenhead, 0 otherwise) |
| SUBURB2 | Dummy variable for a suburb (1 if Browns Bay, 0 otherwise) |
| SUBURB3 | Dummy variable for a suburb (1 if Campbells Bay, 0 otherwise) |

## Appendix A (*Continued*)

| Variable | Description |
|---|---|
| SUBURB4 | Dummy variable for a suburb (1 if Castor Bay, 0 otherwise) |
| SUBURB5 | Dummy variable for a suburb (1 if Devonport, 0 otherwise) |
| SUBURB6 | Dummy variable for a suburb (1 if East Coast Bays, 0 otherwise) |
| SUBURB7 | Dummy variable for a suburb (1 if Forrest Hill, 0 otherwise) |
| SUBURB8 | Dummy variable for a suburb (1 if Glenfield, 0 otherwise) |
| SUBURB9 | Dummy variable for a suburb (1 if Greenhithe, 0 otherwise) |
| SUBURB10 | Dummy variable for a suburb (1 if Hillcrest, 0 otherwise) |
| SUBURB11 | Dummy variable for a suburb (1 if Mairangi Bay, 0 otherwise) |
| SUBURB12 | Dummy variable for a suburb (1 if Milford, 0 otherwise) |
| SUBURB13 | Dummy variable for a suburb (1 if Murrays Bay, 0 otherwise) |
| SUBURB14 | Dummy variable for a suburb (1 if Northcote, 0 otherwise) |
| SUBURB15 | Dummy variable for a suburb (1 if Rothesay Bay, 0 otherwise) |
| SUBURB16 | Dummy variable for a suburb (1 if Sunnynook, 0 otherwise) |
| SUBURB17 | Dummy variable for a suburb (1 if Takapuna, 0 otherwise) |
| SUBURB18 | Dummy variable for a suburb (1 if Torbay, 0 otherwise) |
| SUBURB19 | Dummy variable for a suburb (1 if Waiake, 0 otherwise)<br>The omitted category is 'Albany' |
| CSI | Dummy variable for overall quality of the immediate surrounding (1 if Average and below, 0 otherwise) |
| D_CBD | Distance to Auckland's Central Business District in meters |
| D_PARK | Distance to the nearest park in meters |
| D_COAST | Distance to the nearest coast in meters |
| D_STREAM | Distance to the nearest creek or stream in meters |
| D_MW | Distance to the nearest Motorway Ramp in meters |
| D_TAKAPUNA | Distance to the Local Business Centre, Takapuna in meters |
| DMUL | Dummy variable for Metropolitan Urban Limit (1 if the house is within 1 km from the top part of the MUL, 0 otherwise) |

## Appendix B

## Spatial correlation

As Anselin (1988) explained, in the most general sense, spatial dependence (spatial autocorrelation) can be treated as a functional relationship between what happens at one point in space and what happens elsewhere. More specifically, house prices tend to be spatially correlated because neighbourhood properties share numerous location characteristics (Basu and Thibodeau 1998; Dubin *et al.* 1999).

Spatial dependence can be in two types: substantive or residual. Anselin (1988) introduced spatial autoregressive models which model cross-sectional data in the form;

$$Y = \rho WY + X\beta + u \tag{4}$$

$$u = \lambda Wu + \varepsilon \tag{5}$$

$$\varepsilon \sim N(0, \Omega) \tag{6}$$

where $Y$ is a $nx1$ vector of cross-sectional dependent variables, $X$ is a $nxk$ matrix of explanatory variables, $W$ is a known $nxn$ spatial weight matrix. The coefficient $\rho$ measures the extent to which one observation is dependent on its neighbours and the coefficient $\lambda$ measures the extent to which an error of one observation is associated with the errors of neighbouring observations. Spatial correlation in errors ($\lambda \neq 0$) may result when unobserved variables are spatially correlated (Case 1991). When spatial association is substantial the specified model ($\rho \neq 0$ and $\lambda = 0$) is called a spatial lag model. Spatial error model is specified with $\lambda \neq 0$ and $\rho = 0$. As Anselin (1988) explained, when the spatial association is substantial OLS will lead the parameter estimates to be biased and inconsistent. Residual spatial correlation on the contrary leads OLS estimation to be unbiased but inefficient and may lead to incorrect inferences.

The first step in correcting for spatial dependence is to create a spatial weight matrix $W$ that specifies the structure of potential spatial interaction. Following the empirical evidence, we start with the minimum distance of 0.83 km at which all observations have at least one neighbour as a threshold and experiment by changing the distance around the threshold value.